DC3 Operations Plan

28 April 2012

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Deep Convective Clouds and Chemistry (DC3) Operations Plan

The Deep Convective Clouds and Chemistry (DC3) project involves the deployment of extensively instrumented aircraft to three study regions defined by the coverage of research-grade ground based facilities to gather observations to improve understanding of the role of convective clouds on the composition and chemistry of the upper troposphere and lower stratosphere. State of the art operational and research numerical weather models will provide guidance on storm location, evolution, and other characteristics.

This document provides the detailed plan of the day-to-day operations during the DC3 intensive phase. This plan outlines the process by which DC3 facilities will be deployed, decisions will be made, and resources will be allocated.

1. Project Overview

The Deep Convective Clouds and Chemistry Project (DC3) field campaign investigates the impact of deep, midlatitude continental convective clouds, including their dynamical, physical, and lightning processes, on upper tropospheric (UT) composition and chemistry. The DC3 field campaign makes use of multiple aircraft conducting coordinated flights in conjunction with ground-based observations. The NSF/NCAR Gulfstream-V (GV) aircraft is the primary platform to study the high altitude outflow of the storms, and is instrumented to measure a variety of gas-phase species, radiation, and cloud particle characteristics. The GV is also documenting the downwind chemical evolution of the convective outflow. The NASA DC-8 aircraft complements the GV via in situ observations to characterize the convective storm inflow and provides remote sensing to aid in flight planning and column characterization as well as observations of the outflow evolution. The DLR Falcon aircraft observes the very fresh storm outflow close to the storm core as well as measurements of aged outflow. Ground-based radar networks are used to depict the physical and kinematic characteristics of the storm and provide input to the aircraft operations. The impact of lightning on outflow composition is constrained through detailed measurements from lightning mapping arrays. The forecasting and analysis is improved through other observations such as radiosondes and precipitation collection and its chemical analysis. Satellite data are used to place the airborne and ground-based measurements in the context of the wider geographical region and help guide sampling strategies. At the same time, DC3 measurements help satellite retrievals of atmospheric constituents such as NO_2 near storms.

The observations are conducted in three locations: 1) northeastern Colorado, 2) central Oklahoma and western Texas, and 3) northern Alabama in order to gather data on different types of storms and with different boundary layer compositions as well as to ensure sampling of convection during the time period of the field campaign. The types of storms being sampled are air mass, multicell, and supercell convection.

The DC3 field experiment will improve current knowledge of convection and chemistry by providing a comprehensive suite of chemical measurements within the context of excellent kinematic, microphysical and electrical ground-based measurements. These measurements will provide the necessary information to estimate ozone sources and sinks in the upper troposphere where ozone is radiatively active as a greenhouse gas.

The DC3 project provides broader impacts to society via extensive education and outreach activities, and via improved understanding of sources of UT ozone, an important constituent to climate and air quality, for assessment reports and resulting policy implications. Further, DC3 measurements are instrumental in improving model parameterizations of convective transport, production of NO by lightning, and wet deposition of chemical species. Students from both undergraduate and graduate school are participating in DC3 in a variety of ways including airborne and ground-based observations, design and construction of instruments, operation and improvement of numerical models, and reporting of the results to the scientific community through presentations and publications. Outreach days for the public and media provide a valuable means to engage the public in atmospheric science.

1.1 Scientific Objectives

The Deep Convective Clouds and Chemistry (DC3) field experiment will study the impact of continental, midlatitude deep convection on the UTLS composition and chemistry above the continental U.S. during the lifetime of the storm itself and during the period 12-48 hours after active convection. The primary goals of DC3 are to:

1) *quantify and characterize the convective transport of fresh emissions and water to the upper troposphere within the first few hours of active convection, investigating storm dynamics and physics, lightning and its production of nitrogen oxides, cloud hydrometeors effects on scavenging of species, surface emission variability, and chemistry in the anvil.*
2) *quantify the changes in chemistry and composition in the upper troposphere after active convection, focusing on 12-48 hours after convection and the seasonal transition of the chemical composition of the UT.*

A number of hypotheses related to these goals will be addressed. The hypotheses related to Goal 1 are:

Hypothesis 1. Inert tracers are transported primarily to the upper troposphere within 3-5 km of the tropopause in shear-driven storms, such as those found in Colorado and Oklahoma, and can be used to determine the maximum outflow altitude, which will be different than cloud top height, the level of neutral buoyancy, and the maximum ice content altitude. These same inert tracers are transported throughout the free troposphere in airmass thunderstorms, more common in the southeastern U.S. This implies that shear-driven thunderstorms contribute more to UTLS chemistry, ozone production, and cross tropopause transport than airmass thunderstorms.

Hypothesis 2. In the anvil and near the convective cores, soluble species, e.g. HNO_3, H_2O_2 and CH_2O, will be depleted compared to their background UT mixing ratios because ice scavenges the dissolved species in cloud water within the convective core. Furthermore, because of the short time an air parcel is in contact with liquid water and the high updraft speeds, transport of soluble species to the UT will be more efficient in the high plains (Colorado) storms compared to the storms in northern Alabama. The warmer cloud bases and greater moisture contents in Oklahoma and Al-

abama have larger liquid water regions resulting in more efficient scavenging of soluble species.

Hypothesis 3. The contribution of lightning to NO_x concentrations in the anvil, and subsequently in the upper troposphere, depends on overall flash rates and aggregate channel lengths at heights extending from just above the melting level to the uppermost region of the convective core. The amount of NO_x produced by a cloud-to-ground flash is on average roughly equivalent to that produced by an intracloud flash.

Hypothesis 4. The flash rates of a storm are proportional to the volume of updrafts greater than 10 m s^{-1} in the -10˚C to -40˚C layer and to storm graupel echo volume. Cloud-to-ground lightning occurrence usually follows the occurrence of precipitation in the 0˚C to -10˚C layer after graupel has appeared in this region or higher regions. Conversely, cloud-to-ground lightning occurrence is inhibited in storms that produce little precipitation.

Hypothesis 5. Storms that produce inverted-polarity intra-cloud (IC) flashes in the upper part of storms and inverted-polarity CG flashes are those in which a large fraction of the adiabatic liquid water profile is realized as cloud liquid in the mixed phase region.

Hypothesis 6. The chemical composition of the convective outflow within and near the visible anvil will be stratified into a top layer with high radiation fluxes accelerating radical chemistry, and a lower layer with low radiation fluxes and near nighttime-like radical chemistry.

Hypotheses related to Goal 2.

Hypothesis 7. In sampling the convective plume 12-48 hours after convection, we expect to find that 8-12 ppbv ozone will be produced per day due to high NO_x and enhanced concentrations of HO_x precursor species. The ozone production will vary in a complex nonlinear fashion depending on the NO_x and VOC abundance transported to the anvil from the boundary layer and the amount of NO_x produced by lightning.

Hypothesis 8. Survey flights at the end of June from the central U.S. to the northern Caribbean will find the greatest UT ozone and NO_x mixing ratios above the Gulf of Mexico and Florida. Daily ozonesonde/LIDAR profiles from Huntsville, Alabama will document the seasonal build up and decay of the UT ozone enhancement from May to September.

1.2 Study Regions

These goals and hypotheses will be addressed by sampling convection during May and June in the three locations (Figure 1-1). These locations give us the opportunity to contrast the effects, and the storm processes influencing those effects, on UT composition for regions of remote continental air versus those with air masses more influenced by anthropogenic and biogenic emissions and for the much different storm kinematics and microphysics of regions with abundant boundary layer moisture versus those with drier environments. The locations of the proposed regions are defined by the capabilities of fixed facilities (such as radars), are complemented with mobile facilities, and are set in the context of storm climatology.

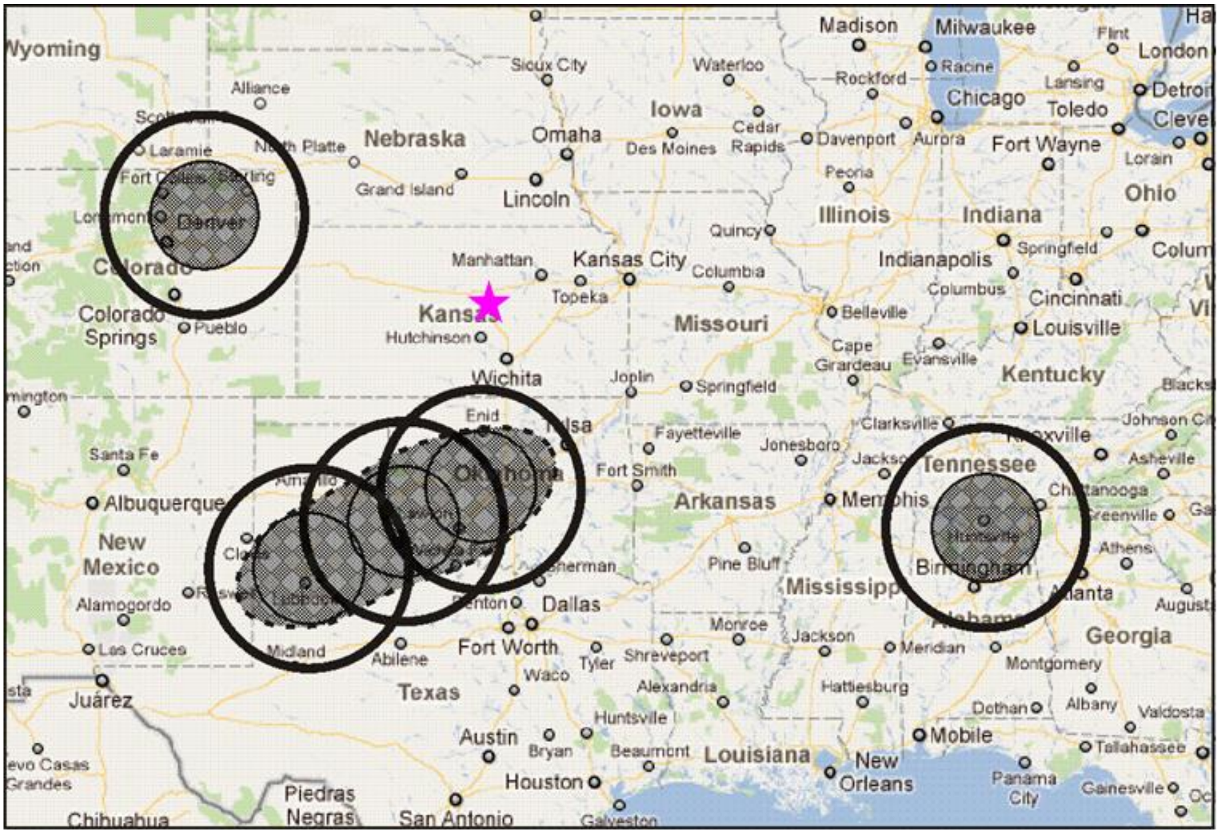


Figure 1-1. DC3 study regions and the base in Salina, KS.

Flight times between Salina, Greeley, CO, Oklahoma City, Lubbock, TX, and Huntsville, AL are shown in Table 1-1.

Table 1-1. Flight times (380 knots ground speed) between the Operations Base in Salina and locations in the three DC3 study regions.

	Greeley	Oklahoma City	Lubbock	Huntsville
Salina, KS	0:52	0:30	0:57	1:28
Greeley, CO	X	1:08	1:05	2:19
Oklahoma City	X	X	0:36	1:21
Lubbock, TX	X	X	X	1:54

1.3 Climatology

Convective storms over the central U.S. are nearly an everyday occurrence during the late spring and summer. These storms range from airmass thunderstorms, to multicellular thunderstorms and supercells, to mesoscale convective systems depending on the instability, wind shear and mesoscale forcing of the atmosphere. These storms can have a significant impact on UT composition as seen from observations taken during the July and August 2004 NASA INTEX-A project. Results from this project showed that much of the UT region over the U.S. is influenced by convection.

Northeast Colorado can experience a clean or polluted boundary layer, depending on the direction of the prevailing winds. Winds from the northeast can be quite clean, while winds that pass over the Denver metropolitan area (pop. 2.4 million, 59 million vehicle-miles/day) can be quite polluted. The emissions come not only from vehicle traffic, but from industrial activities, energy production, and oil and gas drilling. In this region, the convective storms are characterized by high cloud base heights. The central Oklahoma area can also be subject to pollution from the Oklahoma City metropolitan area (pop. 1.2 million, 30 million vehicle-miles/day), the Dallas-Ft. Worth metropolitan area (pop. 6.1 million, 151 million vehicle-miles/day) and emissions from oil production, but also can include biogenic emissions, particularly in the eastern part of Oklahoma. Western Texas should have much cleaner air, as it has few population centers. In northern Alabama, biogenic emissions and urban emissions are both substantial. Surface winds in May and June tend to be southerly (13% of 16 sectors) in northeastern Colorado, south (21%) to south-southeasterly (20%) in central Oklahoma, and east-southeasterly (12%) in northern Alabama.

Oklahoma and Alabama storms have lower cloud base heights than Colorado, and typically have storms with different CAPE levels. These three regions will allow contrast in a number of the controlling variables that affect the ability of storms to transport species to the upper troposphere, thus testing our understanding and leading to improved parameterizations.

The time period for the campaign is based upon climatological analyses of: 1) cloud-to-ground lightning flashes from national and local lightning detection networks; 2) a 10-year convective precipitation climatology; 3) tracer studies of anthropogenic NO_x emissions; and 4) storm frequency climatologies in the three study regions. All of these products can be viewed at: http://www.esrl.noaa.gov/csd/metproducts/dc3/ .

The best time period for the DC3 experiment is May and June. This period has several advantages: 1) The month of June is a good "intersection" month that yields relatively high precipitation often driven by daytime convection at all three sites. This month also provides a high incidence of air mass thunderstorms, with the additional occurrence of frontal driven convection during the first half of the month. 2) The last half of May provides a high incidence of frontal driven convection at all three sites. 3) While MCS and MCC storms occur in this time frame they do not dominate convective activity. 4) This is the best time period for deep, isolated convection within the range of the CHILL radar in northeast Colorado. 5) Including the month of June provides the most daylight hours allowing aircraft missions to extend into the early evening, plus ample daylight for photochemistry studies.

This study period precludes the best time to sample convection associated with the North American Monsoon that dominates during July and August. But this time frame was not recommended because the convection that begins in the afternoon along the Rocky Mountains advects into Kansas and Oklahoma during the night making research flights difficult. These nighttime storms often become very large MCS or MCC storms that are potentially dangerous for aircraft missions.

During the study period, the G-V is able to reach the lower stratosphere, or at least the tropopause layer. This allows us to directly contrast the background UT and LS with the convectively perturbed composition of those regions. Later in the summer, this becomes more difficult, at least from a climatological standpoint.

1.4 Organization

The PIs have been and will continue to be advised by the DC3 Scientific Steering Committee and the DC3 Science Team. The PIs make the decisions and take the actions necessary to carry out those decisions.

The roles of various members of the DC3 Leadership Team in day-to-day operations are summarized below

1.4.1 Roles and Responsibilities

In addition to the persons involved in the project organization, there are a few key positions that enable exchange of information and making decisions during aircraft flight operation periods. These positions and their roles are shown in Table 1-2.

Table 1-2. Key positions and their roles and responsibilities during DC3 flight operations.

Position	Acronym	Roles & Responsibilities
Operations Director	OD	• Oversees the flight operations • views relevant data, consults the decision-making team, and sees that decisions are executed • writes or delegates writing of Field Catalog reports
Asst Operations Director	AOD	• assists the OD in carrying out their duties • helps make and execute decisions
GV Mission Scientist	GV MS	• Works with decision-making team on the ground and the GV MC in developing requests for GV maneuvers
GV Mission Coordinator	GV MC	• Facilitates communication between the GV MS and the GV pilots • advises GV MS and GV pilots on potential severe weather
Communicator w/ GV MS	GV Comm	• Serves as point of contact between ground decision-making team and the GV MS
DC-8 Mission Scientist	DC8 MS	• Works with decision-making team on the ground and DC8 MC in developing requests for DC-8 maneuvers
Communicator w/ DC-8 MS	DC8 Comm	• Serves as point of contact between ground decision-making team and the DC8 MS
DC-8 on-board Project Manager	DC8 PM	• Facilitates communication between the DC8 MS and the DC-8 pilots
Falcon Mission Scientist	Falcon MS	• Works with decision-making team on the ground and the Falcon MC in developing requests for Falcon maneuvers
Falcon Mission Coordinator	Falcon MC	• Facilitates communication between the Falcon MS and the Falcon pilots • advises Falcon MS and Falcon pilots on potential severe weather
Communicator w/ Falcon MS	Falcon Comm	• Serves as point of contact between ground decision-making team and the Falcon
Communicator w/ ground facilities	Ground Comm	• Serves as point of contact between ground decision-making team and the ground facilities (radars, LMAs, sondes) in the targeted sampling region

Position	Acronym	Roles & Responsibilities
Operations Support Director	OSD	• EOL FPS staff member who ensures smooth operation of tools needed for accessing and viewing information, and communicating with DC3 facilities

These positions will be filled by DC3 PIs, SSC members, FPS personnel, GV and DC-8 platform support persons, and other Science Team members. In general, the people who will rotate holding the key positions are listed in Table 1-3, although others could also fill in from time to time.

Table 1-3. Key positions during flight operations, and persons who can fill them.

Position	Persons
OD	Barth, Rutledge, Brune, Cantrell, Crawford, and Cooper (for UT survey flight)
AOD	Barth, Rutledge, Brune, Cantrell, Crawford, and Cooper (for UT survey flight)
GV MS	Cantrell, Flocke, Pan, Crawford
GV MC	A. Cooper, Stith, Rogers
GV Comm	Flocke, Cantrell, Pan
DC8 MS	Brune, Crawford
DC8 Comm	Crawford, Brune, Pickering, Pan
DC8 PM	???
Falcon MS	Huntrieser, Schlager, Weinzierl
Falcon MC	Huntrieser, Schlager, Weinzierl
Falcon Comm	Huntrieser, Schlager, Ziereis, Weinzierl, Heimerl
OSD	Salazar, Moore, Baeuerle, Meitin, Williams

2. Schedule

The aircraft flight hours for the GV and DC-8 are utilized over the period 1 May – 30 June 2012. Test flights will take place in early May (1 to 6), and two "shakedown" flights between 10 May and 14 May. These will involve testing of airborne operations, forecasting, and communications. Regular DC3 flights will be conducted from 14 May to 30 June. The DLR Falcon will conduct scientific research flights between 28 May and 15 June. The calendar for DC3 observational activities is shown in Appendix C1.

Generally, flights will be conducted in the afternoon to coincide with the climatologically expected peak storm periods. Flight operations in the vicinity of storms will only be conducted during daylight hours. Time zone differences and ferry times to study areas are considered in developing the schedules.

2.1 Nominal Daily Schedules

Detailed diagrams of daily schedules for the various scenarios are shown in Appendix C2.

2.1.1 Flight Days

Flights days begin with the Daily Weather Briefing followed by the Daily Planning meeting. A period of aircraft instrument warm-up commences after the meeting.

Taking into account ferry times and storm timing, the earliest takeoff times are about 13:00 CDT for storm studies (no flight the following day) in Colorado and Oklahoma, and 11:00 CDT for Alabama. Providing three hours of instrument and aircraft preparation leads to final decisions at 10:00 CDT and 8:00 CDT, respectively. The Daily Planning meeting occurs at 9:00 CDT and 7:00 CDT, respectively. Flight operations complete around 21:30, 20:30, and 18:30 for Colorado, Oklahoma, and Alabama, respectively.

For storm study flight days that involve an aged outflow flight the following day, the schedule is slightly different. In that case, the schedule is similar to those for Colorado and Oklahoma described above. The earliest takeoff time is 13:00 CDT, with the Daily Planning meeting at 9:00 CDT. Flight operations complete about 19:00 CDT.

For aged outflow flights, the earliest takeoff time is 11:00 CDT, and thus the Daily Planning meeting is at 7:00 CDT. Flight operations would finish about 18:00 CDT.

2.1.2 Non-Flight Days

The schedule for maintenance days includes the Daily Planning meeting at 9:00 CDT, and a period for instrument and aircraft maintenance from about 10:00 to 17:00 CDT. Occasionally, the one-hour period immediately following the Daily Planning meeting (10:00 – 11:00 MDT) will be devoted to presentation and discussion of interesting scientific findings from the campaign.

2.1.3 Other Scheduled Activities

Near the end of each day (flight and non-flight), the weather forecast and instrument status are revised at the Afternoon Weather Forecast Update meeting of decision makers and forecasters. Before the Daily Planning meeting, a 30-minute Weather Briefing is presented to the decision makers.

Approximately every seven days, a hard down day is declared. On those days, no aircraft access is allowed and the aircraft operation teams will not be available. The Daily Planning meeting is held on hard down days.

Confirmation or changing of announced decisions are broadcast via the DC3 Field Catalog, cell phone text message, call-in phone message, email, Twitter and other venues.

2.2 Daily Weather Briefing

Immediately preceding the Daily Planning meeting, the DC3 PIs and other members of the decision-making team are briefed on the weather relevant to ground and aircraft operations (see Section 9). The agenda for the Daily Weather Briefing is shown in Table 2-1. This detailed discussion of the weather is summarized by the Lead Forecaster in the Daily Planning Meeting (Section 2.3). The results of these meetings will also be placed in the DC3 Field Catalog (by Lead Forecaster, Regional Forecasters, and Lead Tracer Forecaster).

Table 2-1. Agenda for Daily Weather Briefing.

Start	Length	Item
0	0:05	Weather overview (Lead Forecaster)
0:05	0:04	NE Colorado weather (CO Regional Forecaster)
0:09	0:04	Oklahoma & Texas weather (OK-TX Regional Forecaster)
0:13	0:04	N Alabama weather (AL Regional Forecaster)
0:17	0:04	Tracer forecasts (Lead Tracer Forecaster)
0:21	0:02	Deployment optimization index (Small/Verlinde)
0:23	0:04	Discussion & recommendations

2.3 Daily Planning Meeting

The Daily Planning meeting serves several purposes. Primarily, it provides a forum to summarize the available information relevant to making decisions about the day's and future day's flight operations. It also provides guidance to the ground facilities on the level of their operations (e.g. no storms, storms without aircraft operations, or storms with aircraft operations). The details of the decision making process are discussed below. The agenda for the Daily Planning meeting is shown in Table 2-2.

Table 2-2. Agenda for Daily Planning meeting.

Start	Length	Item
0	0:10	Weather summary (from Daily Weather Briefing, Lead Forecaster)
0:10	0:05	Tracer forecasts (Lead Tracer Forecaster)
0:15	0:10	Facilities status updates; field data submittal status (Platform MS)
0:25	0:05	Flight plans
0:30	0:20	Discussion of deployment options
0:50	0:10	DC3 PI discussion
1:00		Final decision for day; tentative decisions for next few days; schedules

By the end of the meeting, a final decision on flight operations for the day and tentative decisions (including estimated probabilities) for the next few days is announced.

It is not necessary for all members of the DC3 Science Team to attend each of the Daily Planning meetings. It is important that each platform have a representative, that the forecasting team be represented and that instrument status information be available (gathered in advance by the platform Mission Scientist or their designate). The outcomes of the meeting will be summarized in the DC3 Field Catalog (by Ground Mission Scientist of the Day).

The Daily Planning meetings are broadcast visually and audibly using ReadyTalk (see Appendix G for connection information), allowing those who not present at the Operations Base to participate.

Because of the important information disseminated during the meeting that is needed for decision making, details (e.g. weather, flight plans) presented at the meeting are necessarily kept to a minimum. Science Team meetings are scheduled for presentation and discussion of preliminary scientific results of DC3. Suggestions and questions about the process are addressed outside of the meeting.

2.4 Pre-flight Aircraft Sortie Briefing

On flight days about two hours before takeoff, the pilots, mission scientists, and mission coordinators are briefed by the DC3 PIs and the Lead Forecaster on the weather forecast and the flight plans, including any changes to plans since the “go” decision made earlier in the day. There could be as many as 3 of these briefings required depending on aircraft sequencing.

2.5 Afternoon Weather Forecast Update

The Lead Forecaster provides an Afternoon Weather Forecast Update at ~4:00 pm CDT to provide guidance for any possible operations the next day, addressing the possibility of aged outflow flights as well as storm study flights. This briefing will typically include the DC3 PIs, representatives of FPS and the aircraft platforms, mission scientists, mission coordinators, and other interested participants. Brief summaries will also be given during the Post-Flight Status meetings and placed in the DC3 Field Catalog (by Lead Forecaster).

2.6 Post-flight Aircraft Sortie Debriefing

During ferry back to the Operations Base, the aircraft instrument teams are surveyed by the platform Mission Scientist on the success of their measurements during the flight and the status of their instruments. These are summarized in the Field Catalog and at a short Post-Flight Status meeting after the aircraft return to base by the facility manager or the platform Mission Scientist. The status of the platforms and the ground-based facilities are also briefly summarized. This information will feed into decisions for upcoming airborne deployments.

2.7 Science Team Meeting

Occasionally, perhaps every two weeks or so, a meeting of the Science Team is called to review the status of the mission, including progress toward accomplishing the goals and addressing the hypotheses of the project, and to allow a few members to present interesting science results to the group. These are conducted on aircraft maintenance days or hard down days.

3. Decision Making

In the field, it must be decided on a daily basis which location(s) has (have) a reasonable probability of developing storms that can be studied. It must also be decided whether to study the storm itself (addressing goal #1), or study the aged outflow from a previous storm (addressing goal #2).

These decisions are based on evaluation of:

- weather forecasts
- readiness of the aircraft in consultation with the facility managers
- readiness of aircraft instrumentation
- readiness of ground-based facilities
- balance between the various types and locations of studies needed to address the goals and hypotheses of the experiment

- aircraft flight hours and study days remaining.

During the intensive field phase of the experiment, Daily Planning meetings, Weather Forecast Update meetings, and other meetings of the decision-making team are used to plan upcoming project activities. Alternative deployment goals are also placed on the table for consideration. The approximate timeline for decision-making is shown in Table 3-1.

Table 3-1. Approximate timeline for decision making leading up to aircraft deployment.

Time Relative to Take-Off	Activity
- 2 to 3 days	tentative decisions on whether to deploy the aircraft, the potential type of study, and the location
- 18 hrs (previous evening)	firmer recommendation for aircraft and ground based operations; alternate targets narrowed to one or two; meet with the pilots to finalize candidate flight plans, and select approximate takeoff times; review recommendations and assess deployment probability
- 6 hrs (early morning)	near final decision is made to deploy or not, with alternate target
- 3 hrs	final decision on primary and alternate targets
+ 1-4 hrs	if storm suitable for study doesn't develop, decision on alternate target or abort the flight

While the aircraft are deployed, there is continual communication between the Operations Director and Assistant Director of the Day at the Operations Center, the platform Mission Scientists, the local ground-based radar scientists, the nowcast team, and the other ground-based members of the team. They regularly review the status of the deployment and make recommendations for the optimum observation strategy. During this time, however, the individual aircraft through consultation between their platform Mission Scientist and their pilots are responsible for their own flight tracks and safety.

3.1 Decision Making Factors in Advance of Flight Operations

Several factors are weighed when considering whether to deploy the aircraft, where to deploy them, and which goals and hypotheses to focus on. These factors generally relate to the weather, the readiness of facilities and platforms, and the optimal use of available flight hours within the study period.

A table summarizing the factors (Table 3-2) involved in the aircraft deployment decisions is shown.

Table 3-2. Summary of factors entering into the aircraft deployment decision-making process with sample data entered. Probabilities in the first group of columns range from 0 to 1. Platform readiness is presented as go/no-go (g or ng), and instrument readiness is presented as fraction of measurements ready. Progress toward goals counts up as goals are addressed and multiple successful sorties within a region are completed. With 2 goals and 8 hypotheses, and the intent to address goal #1 four times and goal #2 two times, the factor begins at 0/0 and counts up to 6/8 (goals / hypotheses). The Verlinde / Small index ranges from 0 to 100 indicating the urgency to deploy the aircraft to a specific region on a specific day. The last columns count down the remaining research flight hours. See brief descriptions of goals and hypotheses in Table 3-3 caption. More detailed information can be found in Section 1.1.

Date	**Suitable Storm Probability**			**Platform & Instrument Readiness**			**Progress toward Goals**			**Verlinde / Small Index**			**Flight Hours Remaining**		
	4 / 10						**2 / 10**			**4 / 10**					
	CO	**OK /TX**	**AL**	**GV**	**DC-8**	**Falcon**	**CO**	**OK /TX**	**AL**	**CO**	**OK /TX**	**AL**	**GV**	**DC-8**	**Falcon**
27 May	0.6	0.1	0.2	g /0.9	g /0.9	g /1.0	3/5	4/4	2/3	27 %	83 %	41 %	122	105	35

3.1.1 Probability of Suitable Storms

The climatology of suitable storms in the study regions was discussed earlier (section 1.3). Beyond the climatology, for the most value to the deployment decision making process, a quantitative assessment of the probability of isolated storms within the range of the ground-based facilities on a particular day, within a specific time window, and in a particular study region is needed (to address Goal #1 and related hypotheses). The forecast team provides these probabilities. The Verlinde/Small decision tool also provides probabilities in making deployment decisions (see Section 3.1.5). If isolated storms are rare during the study period, then MCS and squall lines can be studied. These storm types cannot be as fully characterized as isolated storms, and require different flight patterns because of their larger horizontal extent.

All three sites should have air mass and shear driven convection according to the climatology. The decision making process requires quantitative assessment of the relative probability of isolated convective storms on a given day within each of the three study areas as well as an assessment of the ease in reaching and locating aged outflow from the previous day's storms.

3.1.2 Platform Readiness

The readiness of the airborne platforms as well as the ground-based facilities factors directly into deployment decisions. This assessment includes the ability of the aircraft to perform the needed maneuvers and the ability to communicate with the Operations Base. Given the availability of three aircraft for part of the study period, problems with one platform can potentially be covered by the capabilities of the other two. The assessment of platform readiness will be made by the respective Facility Managers in consultation with the pilots, mechanics and other team members.

3.1.3 Instrument Readiness

It is unlikely that all of the instruments on the airborne platforms will work 100% of the time. Some of them are critical to addressing DC3 goals and hypotheses while others provide supporting or confirming information. The readiness of each instrument will be provided by the corresponding instrument PI or team member to the Mission Scientist or respective platform Facility Manager. The following tables (3-3, 3-4 and 3-5) provide estimated relative importance of each instrument for each of the three aircraft in addressing the project goals and hypotheses. These factors are not rigid but are intended to provide guidance on weighing instrument readiness in the decision-making process.

Table 3-3. Estimated importance of GV measurements in addressing DC3 goals and hypotheses (0 = not important or relevant, 100 = critically important).

Instrument / Measurement	**Goals***		**Hypotheses[#]**							
	1	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
TOGA VOCs, OVOCs	100	100	100	100	0	0	0	100	100	80
CAMS HCHO	90	90	0	100	0	0	0	100	100	50
P-CIMS peroxides	90	70	0	100	0	0	0	100	100	50
GTCIMS HNO_3, HNO_4, SO_2, HCl	80	70	0	100	100	0	0	100	80	30
NO_x	90	90	0	100	100	0	0	100	100	80
O_3	100	100	100	50	0	0	0	100	100	100
CO	100	90	100	0	0	0	0	100	100	100
CO_2, CH_4	70	70	100	0	0	0	0	70	70	50
H_2O vapor	100	80	0	80	70	0	0	100	100	50
Total H_2O	100	80	0	80	70	100	0	100	80	0
Radiation	100	100	0	0	0	0	0	100	100	100
SMPS	50	70	0	0	0	0	0	100	80	0
UHSAS	50	70	0	0	0	0	0	100	80	0
WCN	30	50	0	0	0	0	0	50	50	0
CDP	70	30	0	0	0	80	0	70	50	0
2D-C	70	30	0	0	0	80	0	70	50	0
3V-CPI	70	30	0	0	0	80	0	70	50	0
Video	10	10	0	0	0	0	0	0	0	0
ADS	100	100	100	100	100	100	100	100	100	100

* Goal #1 is related to observations of active storms including the inflow and the fresh outflow. Goal #2 is related to observations of aged outflow from previously studied storms.

[#] Hypothesis #1 is related to the transport of inert tracers by storms. Hypothesis #2 is related to the uptake of soluble species by condensed phase water. Hypothesis #3 is related to factors controlling the production of NO_x by lightning. Hypothesis #4 is related to factors controlling lightning flash rates and factors controlling cloud-to-ground lightning. Hypothesis #5 is related to factors controlling inverted polarity intra-cloud lightning. Hypothesis #6 is related to the chemical structure of the anvil and fresh outflow. Hypothesis #7 is related ozone production in aged outflow. Hypothesis #8 is related to the regional buildup of ozone the southeast US and over the Gulf of Mexico.

Table 3-4. Estimated importance of DC-8 measurements in addressing DC3 goals and hypotheses (0 = not important or relevant, 100 = critically important). See brief descriptions of goals and hypotheses in Table 3-3 caption. More detailed information can be found in Section 1.1.

Instrument / Measurement	**Goals**		**Hypotheses**							
	1	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
NO_x, NO_y	90	90	0	100	100	0	0	100	100	80
O_3	100	100	100	50	0	0	0	100	100	100

Instrument / Measurement	Goals		Hypotheses							
	1	2	1	2	3	4	5	6	7	8
ATHOS HO_x	100	100	0	0	0	0	0	100	100	100
NO_2, ΣANs, ΣPNs	90	90	0	100	100	0	0	100	100	80
PANs, SO_2	80	70	0	100	100	0	0	100	80	30
HNO_3, bulk aerosols	90	90	0	100	100	0	0	100	100	80
HNO_3, HCN, peroxs, org acids	90	70	0	100	0	0	0	100	100	50
DFGAS HCHO	90	90	0	100	0	0	0	100	100	50
ISAF HCHO	90	90	0	100	0	0	0	100	100	50
PTR-MS VOCs, OVOCs, CH_3CN	100	100	100	100	0	0	0	100	100	80
WAS VOCs, halo-VOCs	100	100	100	100	0	0	0	100	100	80
DACOM CO, CH_4, N_2O	100	90	100	0	0	0	0	100	100	100
AVOCET CO_2	70	70	100	0	0	0	0	70	70	50
DLH H_2O vapor	100	80	0	80	70	0	0	100	100	50
DIAL O_3, aerosol profiles	100	100	100	50	0	0	0	100	100	100
AMS aerosol composition	30	50	0	0	0	0	0	50	50	0
HD-SP2 black carbon	30	50	0	0	0	0	0	50	50	0
PALMS particle composition	30	50	0	0	0	0	0	50	50	0
LARGE CN, CCN	30	50	0	0	0	0	0	50	50	0
DASH-SP f(RH)	30	50	0	0	0	0	0	50	50	0
AOP aerosol ext & abs	0	0	0	0	0	0	0	0	0	0
SPEC aerosol parameters	50	70	0	0	0	0	0	100	80	0
APR-2 precip, clouds	70	30	0	0	0	80	0	70	50	0
BBR broadband solar, IR	0	0	0	0	0	0	0	0	0	0
SSFR spectral solar, near IR	0	0	0	0	0	0	0	0	0	0
CAFS spectral actinic flux	100	100	0	0	0	0	0	100	100	100

Table 3-5. Estimated importance of Falcon measurements in addressing DC3 goals and hypotheses (0 = not important or relevant, 100 = critically important). See brief descriptions of goals and hypotheses in Table 3-3 caption. More detailed information can be found in Section 1.1.

Instrument / Measurement	Goals		Hypotheses							
	1	2	1	2	3	4	5	6	7	8
O_3	100	100	100	50	0	0	0	100	100	100
NO, NO_y	90	90	0	100	100	0	0	100	100	80
PAN	80	70	0	100	100	0	0	100	80	30
CO	100	90	100	0	0	0	0	100	100	100
CO_2, CH_4	70	70	100	0	0	0	0	70	70	50
VOCs, halo-VOCs	100	100	100	100	0	0	0	100	100	80
CPC part. no >5nm	30	50	0	0	0	0	0	50	50	0
CPC part. no >10nm heated	30	50	0	0	0	0	0	50	50	0
UHSAS particle size dist	30	50	0	0	0	0	0	50	50	0
PCASP particle size dist	30	50	0	0	0	0	0	50	50	0
FSSP size dist.	70	30	0	0	0	80	0	70	50	0
Grimm OPC size dist	30	50	0	0	0	0	0	50	50	0
PSAP absorp coeff.	0	0	0	0	0	0	0	0	0	0
SP2 black carbon	30	50	0	0	0	0	0	50	50	0

3.1.4 Progress toward Science Goals

As part of mission planning and project decision-making, contributions of each deployment of the DC3 facilities toward addressing science goals and hypotheses, and the balance of sorties within the three study regions are assessed. One tool in this assessment is the Progress Summary table (Table 3-6).

Table 3-6. Sample Summary table used to assess progress toward project goals with example data entered. See brief descriptions of goals and hypotheses in Table 3-3 caption. More detailed information can be found in Section 1.1.

Flight #			**Storm Study Goals & Hypoth**			**Aged Outflow Goals & Hypoth**			**Survey UT Reg O3**	**Hours**			**Study Days Rmng**
GV	**DC8**	**Flcn**	**CO**	**OK**	**AL**	**CO**	**OK**	**AL**		**GV**	**DC8**	**Flcn**	
6	5	-		1						8	7	0	54
7	6	-					1			7	6	0	52
8	7	-	1							8	7.5	0	49
-	-	4		1						0	0	5	48
9	8	-			1					8	7	0	47
									1				
Totals			1	2	1	0	1	0	1	31	27.5	5	
Goals			*4*	*4*	*4*	*2*	*2*	*2*	*1*	*143*	*125*	*40*	

3.1.5 Verlinde/Small Optimization Tool

Alongside their many scientific and technical challenges, the DC3 PIs face an economic problem: how best to allocate their constrained resources, particularly flight hours, in ways that maximize the likelihood of achieving mission objectives. This economic problem forms the background against which the PIs confront each day a number of decisions, particularly those involving the timing, destination, duration, and spatial patterns of daily flights. These decisions are challenging: they compel the PIs to evaluate uncertainties regarding the timing and location of isolated convective storms, and to grapple with the inter-temporal optimization problem implicit in allocating scarce resources across time over the course of the field season.

Researchers from Penn State University and Venti Risk Management are developing a tool designed to assist the DC3 PIs with two of their most fundamental daily decisions: whether to deploy aircraft and if so, where to send them.

The tool's design is based on statistical decision theory, a formalism that offers a structured framework for addressing problems of optimization under uncertainty. The tool features two main components: a forecasting module, and an optimization module. The forecasting module ingests output from the Weather Research and Forecasting (WRF) numerical weather prediction model to generate probabilistic forecasts of the likelihood of isolated convective thunderstorms in each of the three DC3 study regions. Based on these probabilities as well as other information (the prospects for successful measurement of aged outflow, flight crew restrictions on the number of consecutive operational days, etc.), the optimization module calculates the respective costs and benefits associated with a flight to each of the several available targets. ``Costs'' are measured in terms of the consumption of flight hours, and the consequent reduction in opportunities to collect data later in the season. ``Benefits'' are measured with reference to an objective function that attempts to encode the scientific goals of the campaign, including the aspiration to collect data in equal amounts from each of the DC3 study regions. The tool then generates a recommendation as to which of the available targets offers the greatest net benefits, in statistical expectation. As the field season progresses, the tool's algorithms re-optimize to take account of evolving conditions including updated forecasts and the track record of successes and failures from earlier flights.

The tool does not and is not designed to address all of the flight decisions confronting the DC3 PIs. It will not address the timing, duration or trajectory of flights. Nor can it inform the optimal placement of mobile ground-based radar units. For these reasons and others, it cannot replace human forecasters. It is likely nonetheless to provide value to the DC3 campaign, mainly in three ways. First, it will provide quantitative probabilities of success that are based on a calibrated model. Because these probabilities are computed algorithmically, they will offer a reliable benchmark for evaluating prospects of success in alternative flight choices. Second, the tool will provide quantitative measures of critical information that is difficult to obtain in any other way: information about the opportunity costs of using up flight hours, and thus foreclosing options to pursue alternative strategies later in the season. Finally, the availability of a coherent and consistent framework for making daily flight decisions promises to clarify the stakes and implications of alternative choices, and thereby to improve the efficiency and efficacy of the decision-making process.

3.2 Decision-Making during Flight Operations

In addition to decisions made on when and where to deploy aircraft, continual decisions must be made during flight operations. These decisions are based on factors that include many of the issues discussed in Section 3.1 (storm location and movement direction and speed, current and predicted storm intensity, and aircraft and instrument function). In order to make such decisions with the best information, it is critical for the most needed data to be transferred to the Operations Base as quickly as possible. These data include radar, lightning, and profile information from the ground-based facilities, measurements (which might be raw voltages proportional to the target species) from the aircraft platforms, and a variety of operational observation and modeling products. The overall capabilities of these facilities are discussed in Sections 6 (aircraft) and 7 (ground-based).

These data will be collected into the DC3 Field Catalog and a subset will be available for viewing on the Mission Coordinator display. These data will be used for decision-making and future planning only. They are not to be viewed as data submitted by the instrument teams. The data will be retained until Field data (for research facilities) is available (see Section 10) and then will be purged.

The aircraft products to be sent to the Field Catalog during flight operations are shown in Figure 3-7. These lists may evolve, but the intent is to have approximately equal information from each of the airborne platforms.

Table 3-7. Products from airborne platforms, marked "X", that are sent to the DC3 Field Catalog for in-flight decision-making.

Item	Aircraft		
	GV	DC-8	Falcon
O_3	X	X	--
O_3 profiles	--	X	--
NO	X	X	--
NO_2	X	X	--
PAN		X	--
NO_y	--	X	--
CO	X	X	--
CO_2	X	X	--
CH_4	X	X	--
Selected VOCs	X		--
Irradiance	X	X	--
Actinic Flux	X	X	--
Water vapor	X	X	--
Dew/Frost Point	X	X	--
Total Water	X		--
Particle number (>10 nm heated & unheated, > 3 nm)	X	X	--
SO_2	X	X	--
$SO_4^{=}$ - bulk inorganic ions	--	X	--
Organic ions	--	X	--
Cloud droplet size distribution	X		--
Single particle composition	--	X	--
Aerosol scattering	--	X	--
Black carbon	--	X	--
Wind direction & speed	X	X	--
Temperature	X	X	--
Static Pressure	X	X	--
Altitude, Latitude, Longitude, Airspeed, Heading	X	X	X
Revised waypoints	X	X	--

3.3 Contingency Plans

Storm behavior predictions are subject to location and timing uncertainties. Also, the airborne platforms could develop problems and severe weather could move into the Salina region (see Appendix N). These issues could require adjusting the flight plans, reducing flight duration, and/or making use of alternate airports. Contingency plans have been developed for such situations to aid in decision making.

3.3.1 Storm Location (Relative to Ground-Based Facilities)

At least two scenarios are conceivable with storms suitable for study but located outside of the domain of the DC3 ground facilities. In one instance, the storm could be well located relative to the ground-based radars, lightning mapping and other facilities, but with time the storm moves out of range. In another instance, a storm predicted to develop within the range of the ground facilities develops outside of range of their capabilities.

In the first case, data on the storm characteristics will be collected by operational radars and lightning networks in addition to the research facilities. As the storm moves out of the range of the research-grade facilities, the operational facility observations can be used to connect the storm characteristics when in the range of research facilities to those when it moves outside of them, albeit with reduced characterization capabilities (e.g. loss of dual-Doppler capability, reduced resolution, loss of 3-dimensional lightning mapping). While the ground-based research observations are critical to addressing DC3 goals and hypotheses, a fairly well-characterized storm that moves out of range could be continued to be sampled by the aircraft, at least for a short time. This would extend the time for characterization of the inflow and outflow, helping to constrain the composition of the fresh outflow, and thus potentially bringing increased understanding to the evolution of aged outflow.

In the second case, the storm characterization would rely completely on operational ground-based facilities (in addition to satellite observations and observations from the airborne platforms). The suitability of such limitations depends somewhat on confidence in the statistics gathered on storms in the various regions so far (with and without concomitant airborne observations). If storms of similar size and intensity are found to have a reasonably narrow range of physical and micrometeorological characteristics, then aircraft studies of storms outside the range of ground-based facilities could address DC3 goals and hypotheses acceptably. In order to gather the needed statistics from the research-grade facilities, it is likely that such studies will only be considered in the later part of the mission.

3.3.2 Storm Intensity (Electrification, Hail, Winds)

Storms that are forecast to be suitable for study could have characteristics that are more (or less) intense than predicted. There is a reasonably wide range of storm properties that could be studied, but it is conceivable that the target storm could become too dangerous for the aircraft to conduct the planned flight patterns. Storms could also not develop to the extent needed to address DC3 goals and hypotheses.

For storms that become too intense for study, there are a few potential contingencies. In the extreme case, if there are no suitable storms in the region and no potential or existing storms in other study regions, the sortie could be aborted. If storms in the primary targeted study region are too intense (or too weak), but suitable storms have or will likely develop in the secondary targeted region, then flight operations could be moved to the secondary region.

Another alternative (see section 3.3.1) is to move to nearby storms that are of the desired intensity but outside the range of the ground facilities. In this case, the considerations discussed above will need to be considered.

A storm under study could grow from a suitable intensity to dangerous levels. In this case there might not be enough time to move to another storm or another region. A decision will be made whether to return to base and/or perform longer distance outflow studies, for example.

3.3.3 Aircraft Problems

See Section 6.2.

3.3.4 Severe Weather at Operations Base

The Operations Base in Salina is subject to stormy weather characteristic of the Great Plains during the study period. The weather at the Operations Base will be forecast and nowcast to help assess whether currently deployed aircraft can return to base, whether to delay or abort planned flight operations, and whether to evacuate one or more aircraft. Dealing with storms near Salina can range from delays in landing or takeoff to landing at alternate airports to temporarily moving the aircraft to other airports (see Appendix N).

The weather situations that could bear on such decisions can range from wind and rain to lightning, hail and tornadoes. The statistical likelihoods of such events are shown in Table 3-8.

Table 3-8. Statistical likelihoods of various severe weather events in and near Salina.

Event	**May**	**June**
Average High/Low Temperatures	77/54 °F (25/12 °C)	87/64 °F (31/18 °C)
Average Foggy Days per month	6	4
Probability of Thunderstorms /month	26%	29%
Average Rainy Days per month	6.9	6.2
Total Monthly Precipitation	4.8”	4.1”
Lightning flash density (fl km^{-2} dy^{-1}) avg/max	0.005/2.3	0.007/3.0
Probability Hail > ¾” diam within 25 mi dy^{-1}	4%	4.5%
Average max wind, 90^{th} percentile max wind	19/27 mph	19/27 mph
Probability Wind > 50 knots within 25 mi dy^{-1}	3%	3.5%
Probability Any Tornado within 25 miles dy^{-1}	0.8%	1%
Probability ≥F2 Tornado within 25 miles dy^{-1}	0.25%	0.22%
Average No. Tornadoes within 50 mi/month	1.5	0.7

Because the GV and Falcon are protected in the hangar, they will need to be evacuated from Salina only in extremely severe weather (e.g. tornadoes, very high winds, large hail). Moderate winds and small hail would probably not trigger the need for evacuation of the aircraft. On the other hand, the DC-8 is staged outside and thus the threshold for the severity of weather requiring evacuation is lower. Moderate winds and even small hail could require its evacuation. Evacuation decisions will come from consideration of NWS-issues weather watches and warnings as well as DC3 forecast/nowcast team assessments.

If there is severe weather that precludes landing in Salina after research flight operations for a relatively short period of time, the aircraft could continue conducting scientific flight operations (following restrictions discussed in Section 6.1) or simply loiter until a safe landing is possible.

A list of potential alternate airports has been developed (Table 3-9). The airports have been contacted (***to be done***) to notify them of the potential for the DC3 aircraft to make use of their facilities. After such a diversion to an alternate airport, the aircraft will return directly to the Operations Base without conducting science directed flights.

Table 3-9. Possible alternate airports if return to Operations Base in Salina was not possible. Airports near Salina are shown in the third column (in case of severe weather in Salina). Airports near the study areas are shown in the last four columns (in case of aircraft problems). Only civilian airports are listed. The distances in bold are closest to the city in the column header.

Airport	ICAO	Distance (nmi)				
		Salina	OK City	Lubbock	Greeley	Huntsville
Topeka Forbes Field	KFOE	**90**	**239**	444	426	507
Oklahoma City Will Rogers World	KOKC	**206**	0	**234**	450	537
Lincoln Airport	KLNK	**126**	329	500	362	601
Wichita Mid-Continent	KICT	**70**	**131**	**331**	379	548
Omaha Eppley Field	KOMA	**159**	363	536	402	594
Tulsa International	KTUL	**180**	**91**	**326**	484	468
Lubbock International	KLBB	377	**234**	0	428	761
Albuquerque International	KABQ	487	442	**252**	335	985
Cheyenne Regional	KCYS	415	484	479	**45**	945
Huntsville International	KHSV	584	537	761	925	0
Birmingham International	KBHM	617	546	757	957	**70**
Nashville International	KBNA	540	524	759	882	**84**
Memphis International	KMEM	428	369	596	766	**168**
Arkansas International	KBYH	234	**167**	408	561	**180**
Atlanta International	KATL	708	657	874	1051	**126**
Dallas-Ft. Worth International	KDFW	365	**156**	**259**	595	521
Rocky Mountain Metropolitan	KBJC	353	450	411	**34**	934
Denver International	KDEN	348	442	401	**34**	929
Colorado Springs Municipal	KCOS	335	403	346	**95**	907
Salina Municipal	KSLN	0	206	377	340	584

4. Operations Base (WG)

The airport in Salina, Kansas (Salina Municipal Airport) was selected as the Operations Base for DC3. A number of factors influenced this decision including the length and weight capacity characteristics of the runway, availability of hangar space for the GV aircraft, space for the other aircraft, suitability of meeting space, availability of vendors for the science team needs, and other factors.

Salina is located near the intersection of I-70 and I-135 (Appendix I). It sits about 81 miles (90 miles driving) north of Wichita, Kansas, 164 miles (175 miles driving) east of Kansas City, and 400 miles (435 miles driving) west of Denver. Its population is about 47,700 (2010). There are several universities and technical schools based in Salina. There are also several major universities within 100 miles. There are 31 hotel and motels, 74 restaurants, and 4 golf courses (2 public). The Bicentennial Center regularly hosts concerts, conventions and other events and seats 7,500.

The Salina Municipal Airport was formerly Schilling Air Force Base. One commercial airline (SeaPort Airlines) provides service to Salina from Kansas City.

The public bus service is CityGo with four routes. There is also intercity bus service to surrounding communities (NCK Express) and there is long-distance bus service (Greyhound).

The city's daily newspaper is *The Salina Journal*. There are 12 FM radio and five television stations that are licensed to broadcast from the city.

Further information on Salina can be found in Appendix B.

4.1 Layout of Salina Airport Facilities

The Salina Municipal Airport (www.salinaairport.com) is operated by the Salina Airport Authority (SAA). Its main north-south runway (17/35) is 12,300 feet long capable of supporting 600,000 pound dual double tandem aircraft (Appendix I). There are also three smaller runways. The airport averages 166 operations per day (2010). There are two fixed base operators (FBOs): America Jet and Flower Aviation. The terminal sits near the southern end of the main runway.

DC3 will use one-half of Hangar 600 during the project deployment period. The entire hangar area totals 42,052 square feet. The hangar doors can accommodate 100 foot wingspans and 28 foot tails. We will also use the office space on the west side (~10,000 square feet) and the customer service center office space (6,300 square feet). The facility has wired (in the office space) and WiFi internet service (throughout the hangar and office space).

Information on the Salina Municipal Airport facilities and other issues related to the Operations Base can be found in the site visit report at:

www.eol.ucar.edu/projects/dc3/documents/DC3_Site_Survey_Report_final.small.pdf

4.2 Uses, Regulations, and Security

The SAA has developed a document describing Rules and Regulations for the use of the Salina Municipal Airport:

www.salinaairport.com/pdfs/FINAL%20-%20SLN%20Rules%20and%20Regs.pdf

The document describes activities that are allowed and prohibited by users of the airport. Refer to the online version of the document for acronyms and definitions, and for any changes that may have occurred. Some of the rules relevant to DC3-related activities at the airport are reproduced in Appendix J.

DC3 Science Team members are required to take a safety briefing prior to using the Salina airport facilities.

5. Project Communications (WG)

Communications between participants, facilities, and team members are critical to DC3 operations. These communications range from virtual attendance at planning meetings to direction of aircraft flight patterns to interactions with ground-based facility teams. DC3 will make heavy use of internet exchange of data, visuals, and chat capability.

5.1 Communication Capabilities

5.1.1 Operations Base

The Operations Base at Salina Municipal Airport is configured with high bandwidth internet connectivity that includes wired and WiFi access. Telephone connections (VOIP) are also available.

Most meetings will be operated with ReadyTalk allowing virtual attendance. Audio will be transmitted via telephone, and video via the web at www.readytalk.com. The connectivity information is given in Appendix G.

During flight operations, Xchat will be used to communicate between the airborne platforms, the ground facilities, and the Operations Base. Various chat rooms will be set up for specific communication purposes (see section 10.4.2).

To keep team members informed of the day-to-day decisions and changes to those decisions, brief broadcast messages will be sent via email, Twitter, made available on a telephone call-in line, and posted on the DC3 project website (www.eol.ucar.edu/dc3).

The internet will be used to access information needed by the decision-making team, such as research model output, operational model output, data from aircraft instruments and ground-based facilities, and other types of information. The main repository for such information is the DC3 Field Catalog: catalog.eol.ucar.edu/dc3_2012/index.html (see section 10.4).

5.1.2 Ground-Based Facilities

Each of the ground-based facilities has slightly different capabilities to communicate information. Most of the fixed facilities (e.g. CHILL, KOUN, ARMOR) have internet connectivity. Some facilities (e.g. MISS, SMART-R, LMAs) make use of cell phones either to send data to a server (which may be accessed via the internet) and/or for voice and text communications.

Each region will have VHF radio capability to use for backup communications with aircraft.

The SMART-R mobile radar team will make use of applications developed for smartphones to send and receive information on the location of target storms, the intended aircraft operations, and the location of the radars. This facility is necessarily approached differently because of the lack of ready internet access.

5.1.3 Aircraft

Both the GV and the DC-8 have SatCom capabilities that allow voice and data exchange. The DC3 project will make extensive use of it. The Falcon also has SatCom capability but is limited to transmission of the aircraft position, airspeed, and heading, so VHF radio communications are used for additional Falcon communications.

The GV payload includes several instruments without dedicated onboard scientists. While we intend to make use of the personnel that are onboard to troubleshoot and perform routine operations under the direction of the instrument PI on the ground (via XChat), we also expect to make use of direct ground to instrument communications (via UDP). Commands can be processed by instrumentation software and then data of various types can be returned by the instrument initiating a command. ***The details of this are being worked out, but will be incorporated into this document when finalized.***

6. Aircraft Operations (WG)

Two aircraft are the core airborne platforms for DC3: the NSF/NCAR Gulfstream V (GV) and the NASA DC-8. These jets are capable of high altitude flight and airspeeds of 400 ktas or more. In addition, the DLR Falcon will participate. Flights hours for DC3 are shown in Table 6-1.

Table 6-1. Airborne platform flight hours for DC3.

Platform	Total	Test & Shake-down	Ferry	Research
GV	165	20	2	143
DC-8	140	10	5	125
Falcon	70	In Germany	30	40

6.1 Capabilities, Payloads, Constraints, Safety

6.1.1 NSF/NCAR GV

The GV is configured primarily to study HO_x radical precursors, and NO_x and O_3 sources and sinks above, below and within the outflow region of convective storms. Most instruments operate autonomously, thus minimizing the number of operators required and maximizing the number of instruments that can be staged. As described above, there are real-time communication between PIs on the ground and personnel on the aircraft and the ability to examine instrument parameters directly. In order to reduce the number of scientific personnel on the G-V, instrument operators are cross-trained to manage several instruments.

Typical GV aircraft performance parameters (per Gulfstream V Product Specifications) are:

- Cruise speed (TAS, maximum cruise power) = 510 knots (+0%, -2%) = Mach 0.885 at 60,000 lbs and at 35 kft.
- Specific range = 187 nautical miles per 1000 lbs fuel burned (± 5%) at 45 kft, Mach 0.80, and at 60,000 lbs.
- FAA takeoff distance = 5990 ft (± 8%) at 90,500 lbs, sea level, and International Standard Atmosphere (ISA) conditions.
- FAA landing distance = 2775 ft (± 8%) at 75,300 lbs, sea level, and ISA conditions.
- Maximum altitude = 51 kft (<15 drag counts, <55,000 lbs total weight).

More details can be found in the Gulfstream V Investigator's Handbook (NCAR, 2006:

http://www.eol.ucar.edu/instrumentation/aircraft/G-V/documentation/g-v-investigator-handbook-1

The NSF/NCAR GV aircraft configuration for DC3 is shown in Table D-1 and Figure D-1 (Appendix D). It includes several cabin-mounted and wingpod-mounted instruments that measure trace gases, aerosol properties and solar radiation. Also present in the cabin are three chemistry operators (members of instrument teams who double to provide hands-on capability for semi-autonomous instruments), the mission scientist for the platform, an airborne mission coordinator, and an RAF technician.

Operation of the GV is subject to several constraints regarding operations and crew duty limitations. The GV will not fly at night in the vicinity of storms. Only ferry flights and flight in regions very far from convective will be allowed. It will also not be flown in hail or graupel. To avoid hail, the aircraft must remain a safe distance from the main storm cell. This can be as great as 20 miles or more from the 40 dBZ reflectivity boundary. The aircraft will also avoid cellular deep convection with tops colder than about -10 °C. These limitations should also help the GV avoid strong turbulence associated with convective storms. Special care will be required to avoid the enhanced turbulence that may be associated with a strong mid- or upper-tropospheric jet. The GV is capable of withstanding occasional lightning strikes, but these will be avoided to minimize potential damage to the aircraft skin and to instruments. RAF requests that anvil sampling be conducted from downwind to upwind so that sampling can be terminated if hazardous conditions are encountered. Severe aircraft icing is also to be avoided. Inability to obtain flight clearances from Air Traffic Control to perform desired research maneuvers could pose serious operational constraints. Such issues should be minimized by the pre-project coordination with the relevant ATC centers.

Flight lengths of around 8 hours were requested in the GV facility request for DC3, which initially appeared feasible for an operations base located at low altitude with adequate runway length. Experience during the TORERO mission in January-February 2012 indicates that maximum flight lengths will likely be somewhat shorter than this. Given the lifetime and speed of movement of storms in the study regions, this should not be a severe limitation. Flights on consecutive days require at least 16 hours between landing and the next scheduled takeoff in order to meet project and crew duty requirements.

If there is severe weather at the operations base, it could delay or cancel flight operations. Since the GV and Falcon are housed in a hangar, very severe weather that would damage the hangar make it necessary to evacuate to a temporary base (see Section 3.3.4).

Onboard crew must undergo an aircraft safety briefing prior to participation in GV flights.

Crew duty limitations apply to the aircraft flight crew, maintenance and technician personnel, other RAF staff, and any other persons flying onboard NSF/NCAR aircraft. These limitations on operations are shown in Table 6-2.

Table 6-2. Crew duty limitations for the NSF/NCAR GV aircraft.

Operations – any 24 hour period	10 flight hours
Operations – any consecutive 7 days	40 flight hours
Operations – any 30 day period	120 flight hours
Consecutive working days	6 days
Maximum crew duty period	14 hours
Minimum crew rest period	12 hours
Consecutive maximum duty days	2 days

6.1.2 NASA DC-8

The DC-8 with its large payload carrying capability (up to 30,000 lbs), will be configured as both a remote sensing platform for the region around the storms and as an *in* *situ* platform for inflow and entrainment regions. The primary remote sensing instrument is an O_3/aerosol LIDAR.

The basic DC-8 aircraft performance parameters are:

- Cruise speed = 450 knots (TAS) = Mach 0.80 for ISA conditions, altitudes greater than 30 kft.
- Maximum range = 5400 nautical miles with a 30,000 lb payload and 150,000 lbs fuel.
- Takeoff distance = 8500 ft with takeoff weight of 325,000 lbs, sea level, ISA conditions.
- Maximum altitude = 41 kft (12.5 km).

Further information can be found in the DC-8 Airborne Laboratory Experimenter Handbook (NASA, June 2002):
http://www.espo.nasa.gov/docs/intex-na/DC8_Handbook-1.pdf

The NASA DC-8 aircraft configuration for DC3 is shown in Table D-2 and Figure D-2 (Appendix D). It includes several cabin-mounted and wingpod-mounted instruments that measure trace gases, aerosol properties and solar radiation. The payload will also include members of instrument teams, the aircraft crew (pilot, co-pilot, flight engineer, and navigator), the mission director, assistant mission director, and two technicians.

Flight safety limitations for the DC-8 are similar to those for the GV. Each participant on the platform must undergo aircraft safety training at the start of the mission. This training covers the use of emergency exits, safety equipment, and survival methods. The DC-8 will avoid hazardous weather conditions including hail/graupel, lightning, icing, and turbulence.

Crew duty limits for the DC-8 are shown in Table 6-3.

Table 6-3. Crew duty limitations for the NASA DC-8.

Operations – any 24 hour period	10 flight hours
Operations – any consecutive 7 days	30-40 flight hours
Operations – any 30 day period	100 flight hours
Consecutive working days	6 flight days, 10 max
Maximum crew duty period	14 hours
Minimum crew rest period	12 hours

Since the DC-8 will not be housed in a hangar, even moderately severe weather (e.g. winds or hail) at the Operations Base could make the evacuation of the aircraft necessary (see Section 3.3.4). If such an evacuation is required, then future airborne operations could be affected, including delay of the next aircraft research sortie.

6.1.3 DLR Falcon

During DC3, the Dassault Falcon 20 from the Deutsches Zentrum für Luft- Und Raumfahrt (DLR) is equipped with *in situ* instruments to study the chemical (mainly NO_x, O_3 and its precursors) and particle distribution within the fresh and aged thunderstorm outflow.

The Falcon 20 is still a very reliable and modern aircraft, even though it has been operating for 36 years by the DLR. Its mechanical and aerodynamical robustness makes it an ideal research aircraft even under extreme situations like thunderstorm research or measurements in the contrail of other aircraft. It has flown in several previous thunderstorm-chemistry related field experiments such as EULINOX, TROCCINOX, SCOUT-O3, and AMMA. The aircraft has flown within radar reflectivities between 20-30 dBZ and as close as 5-10 miles to the 50 dBZ radar reflectivity contours. For DC3, it could fly either in local convection or can refuel when sampling further away from the operations base, since the flight duration is limited to 3-4 hours.

The basic Falcon 20 aircraft performance parameters specifically for DC3 are:

http://www.dlr.de/fb/en/desktopdefault.aspx/tabid-3714/

The DLR Falcon configuration for DC3 is shown in Figure D-3 and Table D-3. Most instruments are cabin-mounted, however some instruments are wingpod-mounted. Due to the PMS probes mounted below the wings, the performance of the Falcon (maximum range and altitude) is reduced compared to normal conditions. For the numbers given above, this reduction in performance has been considered. During the flights, 2 instrument operators, 1 mission scientist, and 1 flight engineer are in the cabin in addition to the 2 pilots.

Flight safety limitations for the Falcon are similar to those for the GV and the DC-8. The exception is a smaller minimum distance the pilots are willing to take the aircraft to the vicinity of storm cores. As opposed to the GV, the Falcon will start to operate in the anvil outflow as close as possible to the storm core and then move downwind. Prior to the campaign, the onboard crew is briefed concerning Falcon safety aspects.

The crew duty limits for the Falcon are shown in Table 6-4.

Table 6-4. Crew duty limitations for the DLR Falcon 20 aircraft.

Operations - any 24 hour period	10 flight hours
Operations - any consecutive 7 days	70 flight hours
Operations - any 30 day period	210 flight hours
Consecutive working days	7 days
Maximum crew duty period	14 hours
Minimum crew rest period	10 hours

6.2 Aircraft Functions

This section describes scenarios of airborne platform function and their impacts on DC3 operations.

6.2.1 Aircraft Functions Nominal

If the aircraft platforms selected for an upcoming sortie, then their readiness must be assessed. Assuming they are capable of nominal flight performance in terms of flight length, speed, maximum altitude, and function of aircraft systems (e.g. cabin pressurization, pilot radar, lightning detection, anti-icing capability, and communications), then flight plans could be executed within safety and crew duty limitations.

6.2.2 Problems with One Aircraft

6.2.2.1 Minor – flight sortie shortened

It is conceivable that one of the platforms could encounter a minor problem that could limit some aspect of its performance. We rely on the respective platform teams to make the judgment whether a platform is ready to undertake a flight. It is also possible that minor problems could arise during a flight. In the case of a two-aircraft coordinated cloud study, if one of the platforms must return to base because of problems, then a decision must be made whether the other platform will continue sampling. Some possible scenarios with minor aircraft problems during a sortie:

<u>Two Aircraft Storm study; in-flight problems with low altitude platform.</u> The remaining aircraft could continue sampling if the cloud inflow composition has been adequately characterized. Depending on success working with ATC, it is conceivable that the remaining platform could occasionally sample the boundary layer. If the inflow composition was not adequately characterized or found to be changing, then a decision to abort the sortie at that point is conceivable.

<u>Two Aircraft Storm Study; in-flight problems with high altitude platform.</u> Depending on the altitude of the outflow, the remaining aircraft could change to outflow sampling. As above, it could attempt to sample both the boundary layer and the outflow composition. If such an approach is not conceivable, then a decision to abort the sortie at that point is conceivable.

<u>Two Aircraft Aged Outflow Study; in-flight problems with one platform.</u> Depending on whether the outflow has been located, whether the problem is with the DC-8 (with remote sensing capability) or the other aircraft, and the amount of time the outflow has already been sampled, the sortie could continue as planned with the remaining aircraft, be shortened, or be terminated immediately.

6.2.2.2 Major – flight sortie terminated

A major problem in-flight with one aircraft in a two aircraft sampling scenario may or may not result in termination of a sortie. It depends on an assessment of whether the remaining aircraft can obtain data useful for addressing DC3 science goals and hypotheses. A major problem uncovered before commencing a flight would likely result in aborting the planned flight.

A difficult aspect of platform problems will be assessing whether problems are major or minor. We will be conservative and make full use of information provided by aircraft teams, deferring to pilots in all cases.

It is possible that an aircraft problem could preclude returning to the Operations Base immediately (see Section 3.3.4). This situation could impact future aircraft operations depending on the delay. Aircraft deployment plans need to include scenarios for such a situation.

Adequately addressing DC3 goals and hypotheses could be compromised if a platform has an extended period in which research flights were not possible (e.g. after a severe lightning strike). The decision-making process, in consultation with the funding agencies, will address this situation if it arises.

6.2.3 Aircraft Factors Associated with Aborting Sorties

Each DC3 aircraft has a maximum gross landing weight. Therefore, if a sortie is shortened or aborted after the aircraft are airborne, then consideration of this limitation could become a factor. Shown in Table 6-5 are empty weights, estimated takeoff weights for various flight lengths (with assumptions of extra fuel needed for profiling), and estimates of the flying time needed to get to the platform gross landing weight (as an alternative to dumping fuel).

Table 6-5. Aircraft weights and flying times relevant to shortened sorties and landing weights.

Aircraft	**Maximum Landing Weight**	**Zero Fuel Weight***	**Estd Takeoff Weights for Planned Flight Lengths (hr):**			**Flight Time to Maximum Landing Weights**		
			Short - 5	**Med - 6.5**	**Long - 8**	**Short**	**Medium**	**Long**
GV	75,300	51,200	71,700	77,300	83,000	0	41	154
DC-8	240,000	170,000	231,000	249,000	267,000	0	44	134
Falcon	28,880	22,490	30,325[#]	--	--	39	--	--

* Zero fuel weight includes platform plus payload and crew.
[#] Falcon maximum fuel leads to flights of about 4 hours.

6.3 Aircraft Instrumentation Functions

In order to address specific DC3 science goals and hypotheses, ancillary goals, and unexpected findings, all of the measurements made aboard the aircraft platforms contribute. There are, however, some measurements that are critical to addressing specific objectives (see Section 3.1.3). All instruments occasionally have problems and do not return their highest quality data 100 percent of the time. It will necessary for the decision-making process to consider instrument readiness as one of the factors in weighing deployment decisions. In some situations, minor adjustments to flight plans could cover loss of a particular measurement by making use of measurements on the other platform. Whether this is possible depends on the specifics of the storm and which instruments are having problems. It also depends on how much previous flights have addressed the specific goals and hypotheses.

6.4 LIDAR Operations and Safety

NASA Langley operates an ozone Differential Absorption Lidar (DIAL) system on the NASA- DC-8 aircraft as part of atmospheric science field missions. This instrument provides high priority measurements that are mission critical to most of the airborne science missions. Specific field campaign details are provided several months before the mission which includes the location and duration of operations. This has included both operations in the United States and international operations. The full safety plan for this instrument is reproduced in Appendix M.

6.5 Single Aircraft and Coordinated Aircraft Flight Plans (WG)

A number of flight pattern segments have been developed to allow measurements to characterize the location and composition of background air, storm inflow, anvil, fresh outflow, and aged outflow. These segments are assembled into 6-8 hour flights for either one aircraft or for two aircraft coordinated sorties. Obviously, such flight plans assume ideal storm conditions, nominal aircraft status, and good cooperation from ATC.

Flexibility will be absolutely necessary because deviations from ideal situations can be expected.

The flight pattern segments (shown in Appendix E) are numbered according to the following:

- **1** – storm study [goal #1, hypotheses #1-6]
- **2** – aged outflow [goal #2, hypothesis #7]
- **3** – regional UT ozone survey [hypothesis #8]
- **4** – calibration, zeroing, and intercomparison

Within each numbered category, the segments are assigned an identifying letter. Each segment has a few parameters that define its extent. This includes altitude, length, spacing (vertically and horizontally), number of repetitions, distance from storm core, and so on. Most of the segments can be accomplished by any of the aircraft. The exceptions are 2E and 1F, 2F which require remote sensing capability that is only available on the DC-8.

- 1A, 2A. The segments are designed to sample anvils, fresh outflow and aged outflow across the axis of the outflow direction. Stacked legs (walls) are performed at one distance from the storm core, and then repeated at several distances downwind. The leg altitudes are selected to penetrate the outflow/anvil at several locations as well as sample above and below.
- 1B, 2B. This is an alternative method to sample anvils, fresh outflow, and aged outflow across the axis of the outflow direction by performing several cross axis legs at one altitude, and then repeating the pattern at several altitudes.
- 1C, 2C. This pattern segment samples anvils, fresh outflow and aged outflow along the axis of the outflow direction. Several legs are performed at various altitudes within the outflow/anvil as well as above and below.
- 1D, 2D. Profiling the composition of air upwind and/or outside of the storm, through the anvil (including above and below the anvil), fresh outflow, and aged outflow is the essence of this pattern segment. In storm studies, the two aircraft could sample the upper and lower portions of the profile, respectively.
- 2E. This pattern segment is used to locate the aged outflow given forecast and tracer information as well as remote sensing data from the DC-8 (pattern 2F).
- 1F, 2F. The remote sensing capability of the DC-8 is used to help locate the aged outflow using zig-zags in the vicinity of the forecast outflow location. The remote sensing instrumentation is also used to characterize the composition below the anvil and in fresh outflow as well as the proximity of stratosphere to the storm.
- 1G. This segment is used to examine the horizontal and vertical composition of the storm inflow using circular patterns around the storm core.
- 1H. Short legs at various low altitudes in the storm inflow region are conducted to characterize the inflow composition.
- 1I. This segment uses a “lawn mowing” pattern to examine the horizontal and vertical composition of the storm inflow.
- 3A. A path through the region of expected seasonal ozone buildup with several *en route* profiles.

- 4A. Patterns such as these are used for comparisons of like instruments on two aircraft by performing legs of moderate length side by side or following, usually in transit to the study region or when returning to the Operations Base.

(Combinations of these pattern segments will be assembled for full flight patterns for single aircraft and for two aircraft sorties)

6.6 Aircraft Instrument Intercomparisons

Comparisons of instruments that measure the same quantities, particularly on different platforms, are critical to the DC3 experimental design. For example, to understand the efficiency of transport of soluble and partially soluble species through the storm requires knowledge of the concentrations in the inflow and in the outflow. Since the plan is to often have these two locations sampled by different aircraft, it is imperative that the measurements between various instruments be harmonized. There are also some redundant measurements on the same aircraft. Comparison of those data provides information on the reliability of precision and accuracy estimates. We also encourage measurement teams to exchange standards and provide those data to the archive as well.

Field comparison data are submitted as described for other data, but are held from release to the archive until all data of comparable quantities is submitted. A DC3 Comparison Referee will process the comparison data according to procedures developed by the DC3 Data Steering Committee, and present them to the DC3 Science Team. This analysis and presentation will be done quickly to help instrument PIs detect problems they may have with their instruments or data reduction procedures while in the field.

A summary of comparable measurements is shown in Appendix F.

6.7 Test flights and Shake-down flights

In May, 2011, tests of new GV instruments and of DC3 communications and decision making procedures were conducted. This exercise was critical in improving the plan for use of facilities for DC3. At the beginning of the DC3 campaign (first week of May, 2012), similar practice exercises are conducted to iron out any problems with communications and to exercise the decision making process.

The schedule calls for test flights out of respective aircraft home bases during the first week of May 2012. The GV and DC-8 will then ferry to Salina early in the second week of May. One or more “shakedown” flights will then be conducted to test communications, coordinating two aircraft, and the decision-making process. Plans for these flights will include assembling selected flight plan segments (Appendix E) initially performed in clear air over in the study regions. A second shakedown flight could involve flights near storms, if the opportunity arises. Full DC3 research operations will begin about 14 May 2012 (see Section 1.5).

7. Ground-Based Facilities Operations (WG)

7.1 Colorado

This region is situated adjacent to the major metropolitan area of Denver and surrounding suburbs. Figure 7-1 illustrates the locations of key ground-based observational facilities available to DC3 in this area.

The centerpiece of the observational suite is the advanced, CSU-CHILL S-band Doppler and polarimetric radar maintained by Colorado State University under a cooperative agreement with the National Science Foundation. Located 45 km to the north of CHILL is the CSU-PAWNEE radar, which is an S-band Doppler radar. These two radars form a dual-Doppler pair providing characterization of 3-D winds in precipitation. Two NEXRAD radars, one near Denver (KFTG) and the second at Cheyenne, WY (KCYS), complement this dual-Doppler pair. Additional dual-Doppler coverage is afforded by a KFTG-CHILL pair, and a KCYS-Pawnee pair, thus providing extended dual-Doppler coverage over a large domain. Software is already in place at the CHILL facility to ingest radar data from the other three radars and derive near real-time dual-Doppler wind estimates, overlain with precipitation and hydrometeor identification fields derived from CHILL. This software provides a rich environment for real time decision-making and aircraft guidance during DC3, and will also provide invaluable information for the post-analysis of the storms.

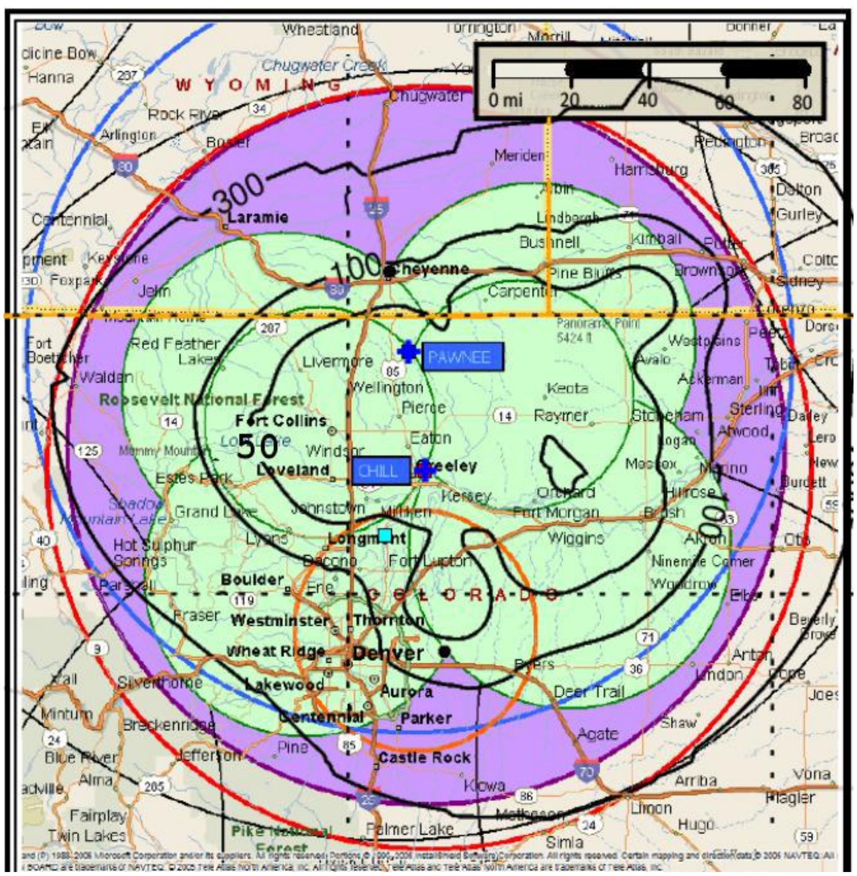


Figure 7-1. Map of ground-based facilities in northeastern Colorado. Radar coverage is provided by the CSU-CHILL facility near Greeley, the PAWNEE radar, and the NEXRAD radars near Denver and

Cheyenne (black circles). The polarimetric coverage for CHILL is indicated by the red circle and the non-polarimetric coverage for PAWNEE is indicated by the blue circle. Dual-Doppler coverage by combinations of these radars is shown by the filled green circles. The filled purple circle shows the coverage of the lightning mapping array (LMA) network. The black contours show the theoretical error (in meters) in locating the vertical position of a VHF lightning source in the 6-8 km height range by the LMA. The orange circle shows the Class B controlled airspace for Denver International Airport.

CSU-CHILL and the Pawnee radars will perform dual-Doppler plan position indicator (PPI) sector scan volumes of significant convection in range of the network, both during aircraft operations as well as during days without aircraft. There will be three basic scan plans.

Scan Plan 0 (no aircraft or precipitation in range): Basic 360° PPI surveillance, 1-3 tilts. Run only to search for targets for more detailed scanning.

Scan Plan 1 (precipitation in range, dual-Doppler not yet started): Canned (fixed elevations) PPI sector volume, designed to be implemented quickly so that detailed scanning of convection can occur while dual-Doppler scanning is coordinated via communications between the two radars. This would likely be run for 1-2 volumes max. Single range-height indicator (RHI) sweep can be interwoven to establish storm echo top height to assist dual-Doppler scan design.

Scan Plan 2 (dual-Doppler, whether in support of aircraft or not): Coordinated dual-Doppler PPI sector volumes between CSU-CHILL and Pawnee. Use 5-min update cycle in most circumstances. CSU-CHILL and Pawnee can complete a 120° sector with 15 tilts in this time period (a 150° sector would require 6 min for the same number of tilts). Short (1 min or less) RHI sector or single-tilt PPI surveillance can be run at the discretion of the radar scientist, with no more than 1 of these between successive PPI sector volumes. A 180° sector can be run if widespread convection exists, but will require 6 min to do 13 tilts. Due to the limited number of tilts CSU-CHILL can perform, specific elevation angles will need to be adjusted by the radar scientist based on distance to storm and its height. The goal will be 1 km or better vertical resolution at storm range, while also topping the storm. Sector width (120, 150, or 180°) will be set by the radar scientist based on storm size and position.

On aircraft days, CSU-CHILL will operate in alternate-transmit mode, preserving linear depolarization ratio (LDR). This provides the timing discussed above. On non-aircraft days, CSU-CHILL will be sped up by operating in simultaneous-transmit mode. This cuts the above volume times by up to 1 min each. Based on the situation, the radar scientist will decide whether to invest this savings into quicker volume updates or better vertical resolution (more tilts). For example, analyses of fast-moving isolated convection may be better served by rapid updates, while analyses of larger storm systems likely would derive more benefit from enhanced vertical resolution.

Synching of dual-Doppler volumes will generally follow common times (hour, H, plus 5 min, H+10, H+15, etc.) to facilitate scanning during missing or congested communications between the radars. Deviations from this are allowable if the conditions warrant.

At times convection may not be well placed relative to CSU-CHILL/Pawnee lobes, but may fit within lobes formed by Pawnee and the Cheyenne NEXRAD radar, or by CHILL and the Denver NEXRAD. Under these circumstances, dual-Doppler will be executed by synching the appropriate research radar to the approximate timing of the respective NEXRAD, which will be estimated based on the timing of recent NEXRAD volumes (available from real-time imagery) and the NEXRAD's current volume coverage pattern (VCP).

As can be seen, while providing some basic guidelines, the Northern Colorado DC3 radar operations plan leaves considerable scanning discretion to the radar scientist(s). On aircraft days, this position will be led by an experienced scientist. On non-aircraft days students will coordinate the radar scanning to provide a valuable learning experience. Under most circumstances, radar scientists will work out of CSU-CHILL.

Near real time dual-Doppler will be carried out between CHILL and Pawnee and these products will be available on the Internet with about 2-3 minute latency.

Data formats: The CHILL and Pawnee data will be archived in DORADE format and sent to the EOL data archive within 1-2 days following the data collection. CHILL data images from the HAWK data system (details still to be determined) will be sent in real time for dissemination through the Mission Control display.

These radar platforms are embedded within a 15 station VHF Lightning-Mapping network (COLMA) installed by the New Mexico Institute of Mining and Technology and operated by NMIMT and CSU. This network will provide estimates of lightning locations and lightning channel geometries throughout the region mapped by the dual-Doppler radar pairs. Collectively these measurements will provide detailed maps of storm kinematics, microphysics, flash rates and flash locations in deep convection, thus addressing central goals of DC3.

The Mobile Integrated Sounding System (MISS) will be used to characterize the vertical profiles of temperature, pressure, relative humidity, and winds.

7.2 Oklahoma & Texas

The ground-based facilities operating in Oklahoma and western Texas are shown in Figure 7-2.

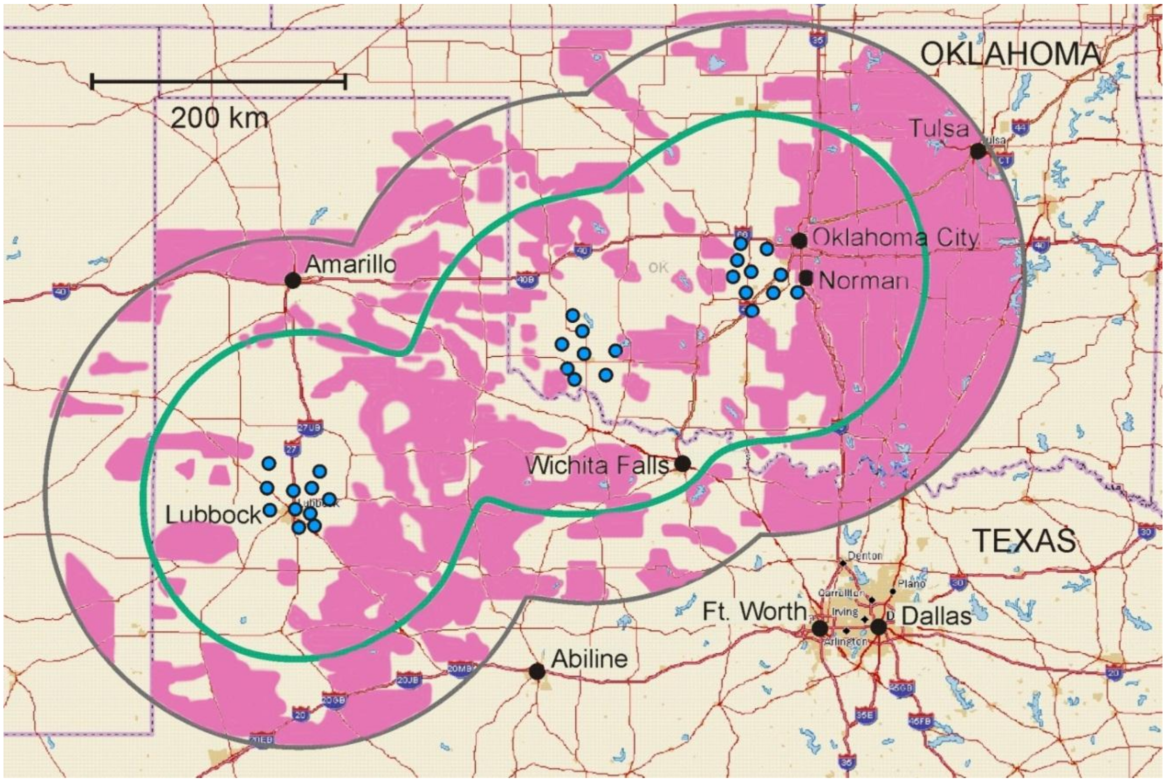


Figure 7-2. Map of ground-based lightning mapping facilities in Oklahoma and western Texas. The blue circles are LMA stations, and the green outline shows the extent of three-dimensional lightning mapping capability. Two-dimensional lightning detection extends to the gray outline. The filled pink areas indicate locations where it is not possible to stage the SMART radars due to lack of roads or to hilly terrain.

Three-dimensional lightning mapping is provided by the existing Oklahoma Lightning Mapping Array (OKLMA), operated by the University of Oklahoma (OU) and the NOAA/National Severe Storms Laboratory (NSSL). DC3 lightning coverage will be extended well in the Texas Panhandle region through a new LMA network (WTLMA) installed around Texas Tech University in Lubbock, TX. This network is supplemented by 3-6 deployable LMA stations, to extend the region of three-dimensional lightning mapping.

The OK-TX network has both fixed site and mobile radar components. The fixed site instruments are all located within Norman, OK and include the S-band dual-polarimetric testbed WSR-88D radar (KOUN), the S-band Multifunction Phased Array radar (MPAR) and the 0.5° beamwidth C-band dual-polarimetric OU-PRIME. The mobile radars consist of the X-band dual-polarimetric NOXP radar, the C-band Doppler SMART radar (SR1) and the C-band dual-polarimetric SMART radar (SR2). The Doppler SMART radar (SR1) may be unavailable at the start of DC3 due to a delay in its return from the Maldives where it supported the NSF/DoE DYNAMO project.

Four other WSR-88Ds fall within the OK-TX LMA network: Amarillo, Lubbock, Fredrick, and Vance. The Vance and Amarillo radars have been upgraded to dual-polarimetric capability.

NSSL also operates a mobile ballooning facility that uses Vaisala GPS radiosondes to track balloons and provide soundings of wind and standard thermodynamic parameters for the environment in which storms occur, an essential data set for storm modeling. This system also is used for larger balloons carrying instruments inside storms to measure the vector electric field and to provide precipitation imaging along the balloon track. Balloons for *in situ* storm measurements are typically launched into updrafts, but after ascending may descend through the rainy downdraft.

Also available are the radar, lidar, precipitation, and atmospheric state measurements at the two Oklahoma ARM sites: the Central Facility near Lamont in northern Oklahoma, and the Kessler Farm near Washington in central Oklahoma. A detailed list of available instruments is provided on the web site, http://www.arm.gov/instruments/location.php. These facilities are supported by the Department of Energy.

Surface observations of the background wind field and thermodynamics will be provided throughout Oklahoma by the extensive grid of Oklahoma Mesonet (http://www.mesonet.org/) stations operated by the Oklahoma Climatological Survey (OCS). These surface data are supplemented in south-central Oklahoma by a network of four CASA X-band radars that scan low elevation angles.

7.2.1 OK-TX Radar Scanning Strategies

7.2.1.1 Radar operating modes

7.2.1.1.A Doppler-only mode

The mobile radars can operate in staggered pulse repetition time (staggered PRT) mode that extends the effective Nyquist velocity to more than ± 40 m s^{-1}. However, due to the non-uniform sampling of the time-series data, spectral clutter filtering and dual-polarimetric measurements are not available in staggered PRT mode.

Given the extreme wind shear that occurs in supercell storms and the need for accurate mass flux in the storm, the mobile radars will operate in staggered PRT mode with short-pulse (<0.5 microsec) waveforms during supercell sampling. The short-pulse allows for shorter PRT, within the duty cycle limitations of the transmitter, and greater effective Nyquist velocities. If needed for clutter filtering, a **hybrid scan,** in which the lowest 2-3 tilts are single PRT and higher elevation tilts are staggered PRT, will be implemented.

The fixed-site radars cannot operate in staggered PRT mode. MPAR is vertically polarized and will collect Doppler data using a combination of adaptive scanning and coordinated scanning to sample at twice the rate of the mobile radars.

7.2.1.1.B Dual-polarimetric mode

All the dual-polarimetric radars, including OU-PRIME and KOUN will operate in Simultaneous Transmit and Receive mode using a single PRT. To improve phase noise characteristics of the transmit waveform, a longer pulse duration (~0.8 microsec) will be used. Doppler measurements are, of course, still collected in dual-pol mode. Nyquist velocities will range from approximately ±15 m s^{-1} for NOXP to ±25 m s^{-1} for KOUN.

Since wind shear in isolated multicell and small multicell clusters is generally weak, single-PRT Nyquist velocity ranges are acceptable for sampling these storm types.

7.2.1.2 Storm Sampling Methods

7.2.1.2.A Target within 100 km of Norman, OK

Table 7-1 summarizes the coordination and temporal sampling for target storms close to central Oklahoma where the fixed radar assets provide enhanced coverage of the storm. In this configuration we obtain at triple-Doppler (C, C and X band) coverage with potential for quad-Doppler wind retrievals with MPAR or extension of the wind retrieval domain by using MPAR as the easternmost radar along a common baseline with the C-bands. We will also obtain coordinated C and S-band dual-pol measurements with OU-PRIME and KOUN for supercells and coordinated C and X-band dual-polarimetric observations with SR2 and NOXP for multicell storms.

In terms of spatial resolution, for a 120° azimuthal sector, the mobile radars can accomplish ~23 PPI tilts from 0.5 to 50° in elevation during a 3-min scan in Doppler mode (rotation rates up to 6 rpm). OU-PRIME scanning speeds are comparable to KOUN (about 14 tilts in 5 minutes) while MPAR can easily match the mobile radar's spatial resolution within half the mobile radar scanning time.

If one of the mobile C-bands are unavailable, the storm-scale (30-40 km) baseline will be formed using with MPAR and SR2 with NOXP providing triple Doppler coverage. Otherwise, the base wind retrievals will depend on SR2 and NOXP, with MPAR helping to extend the wind retrieval domain. It should be noted that X-band attenuation is expected to be large for supercell thunderstorms.

Table 7-1. Summary of radar scanning for storms near central Oklahoma.

Radar	Coordinates with	VCP update time	PPI or RHI sector	Mode
SR1	SR2, NOXP	3 min	120° PPI	Doppler
SR2	SR1, NOXP	3 min	120° PPI	either*
NOXP	SR1, SR2	3 min	120° PPI	either*
MPAR	SRs and NOXP	90 sec	90° PPI	Doppler
OU-PRIME	KOUN	5 min	180° PPI	dual-pol
KOUN	OU-PRIME	5 min	360° PPI	dual-pol

*SR2 and NOXP will operate in Doppler-only mode during supercells and dual-polarimetric mode during multicell storms.

7.2.1.2.B Target beyond 100 km range of Norman, OK

Table 7-2 summarizes the coordination and temporal sampling for targeted storms outside central Oklahoma where the fixed radar assets in Norman are unable to contribute to the storm sampling. In this configuration during supercell events, dual-Doppler (C and C band) is emphasized, with NOXP providing dual-polarimetric X-band observations. If time permits, SR2 conduct a few dual-pol RHIs through the precipitation core between PPI sector volumes.

During multicell events, both SR2 and NOXP operate in dual-polarimetric model.

Table 7-2. Summary of radar scanning for target storms outside central Oklahoma.

Radar	Coordinates with	VCP update time	PPI or RHI sector	Mode
SR1	SR2, NOXP	3 min	120° PPI	Doppler
SR2	SR1, NOXP	3 min	120° PPI	either*
NOXP	SR1, SR2	3 min	120° PPI	dual-pol

*SR2 will operate in Doppler-only mode during supercells and dual-polarimetric mode during multicell storms.

If one of the C-band radars is unavailable, storms close to WSR-88Ds are favored to take advantage of the 88D capabilities to provide dual-Doppler coverage with the remaining C-band while NOXP concentrates on the dual-polarimetric characteristics of the storm (Table 7-3). The C-band conducts more frequent sampling than the 88D to feed into data assimilation wind retrieval methods. If we are coordinating with Vance or Amarillo 88D, then dual-frequency dual-polarimetric measurements at S and X bands are also available.

Table 7-3. Summary of radar scanning for targeted storms outside central Oklahoma, close to a WSR-88D and one of the C-bands unavailable.

Radar	Coordinates with	VCP update time	PPI or RHI sector	Mode
C-band	WSR-88D, NOXP	2.5 min	120° PPI	Doppler (SR1) either (SR2)*
WSR-88D	SR2, NOXP	5 min	360° PPI	Doppler
NOXP	SR2, WSR-88D	5 min	120° PPI	dual-pol

*SR2 will operate in Doppler-only mode during supercells and dual-polarimetric mode during multicell storms.

If the target storm falls outside the nominal range for wind retrievals with the WSR-88D, both the C-band and NOXP default to their 3-minute 120° sector scan Doppler-only modes of operation.

7.3 Alabama

7.3.1 Network Overview

7.3.1.1 Radar

The DC3 Alabama operations area is covered by a multi-Doppler network comprised of two UAHuntsville research radar and the Hytop, AL (KHTX) Weather Surveillance Radar – 1988 Doppler (WSR-88D) (Fig. 7-3). The Advanced Radar for Meteorological and Operational Research (ARMOR) C-band dual-polarimetric radar is located at the Huntsville International Airport. The MAX (Mobile Alabama X-band) dual-polarimetric radar is truck-based but will be deployed to a fixed site near New Market, AL, which is 42.5 km north-northeast of ARMOR. KHTX is located 34.9 km east of MAX or 70.3 km northeast of ARMOR. The NOAA NWS KHTX (S-band) operational radar has been upgraded to dual-polarimetric capability. The three radars will provide high temporal and spatial resolution dual-polarimetric, multi-Doppler observations of storm microphysics and kinematics over the operations domain of the NASA MSFC Northern Alabama – Lightning Mapping Array (NA-LMA) domain (Fig. 7-3). A number of other WSR-88D radars in Fig. 7-3 provide regional coverage of the larger DC3 Alabama area and several have been upgraded to dual-polarimetric (KBMX, KOHX, KFFC, KNQA, and KMRX). Details on radar operations and scanning can be found in Sec. 7.3.2.

7.3.1.2 Lightning Mapping Array

The NASA MSFC owned and operated NA-LMA is comprised of eleven VHF-based lightning sensors over Northern Alabama that are supplemented by two Georgia Tech sensors located near Atlanta, Georgia (Fig. 7-3). NA-LMA height location errors are < 1000 m everywhere within the triple-Doppler radar network and are < 500 m within the ARMOR-MAX dual-Doppler domain (Fig. 7-3). In fact, the altitude location errors are < 100 m inside the NA-LMA network interior. NA-LMA flash detection efficiency is optimal within about 150 km of the center of the network even though flashes can be detected out to 250+ km (Fig. 7-3, green range rings). NA-LMA decimated sensor data are received and processed on NASA MSFC servers at NSSTC in real-time for the production of VHF source data (in NMT ASCII LMA format) and imagery (VHF source density vertical composite and 6000 ft layer composites in KML format) for upload to the DC3 Field Catalog.

7.3.1.3 Mobile Sounding Unit

The UAHuntsville InterMet-3150 upper air sounding system will be used to launch weather sondes. The system is fully mobile (laptop, iMET-1 radiosonde, and receiver) and will be operated out of the back of a UAHuntsville pickup truck or utility van by a 3 person team. Inter-Met is a PC-based system that provides real time processing of field data (ASCII format), quality control and display. The RAwinsonde Observation (RAOB) package will also be employed to analyze the field data and produce skew-T imagery. Field data and skew-T imagery will be uploaded from the Mobile Sounding Unit to the DC3 Field Catalog via cell. On aircraft operations days, sufficient personnel and resources will be available to launch pre-convective (1-2), inflow proximity (3-4) and post-convective (1) sondes within and nearby the general multi-Doppler network (Fig. 7-3, white area), subject to the availability of good roads and launch locations. Depending on meteorological and logistical conditions, sonde launches will be obtained within about 20-40 km ahead of active convection, which is being sampled by aircraft and radar, to mitigate cloud contamination while still sampling inflow proximity conditions. Based on the morning forecast, the mobile sounding unit may be pre-deployed up to 70-80 km ahead of anticipated convective areas in order to facilitate the mobile logistics of pre-convective and inflow proximity soundings. If appropriate, sondes can also be launched from a fixed location at the NSSTC building.

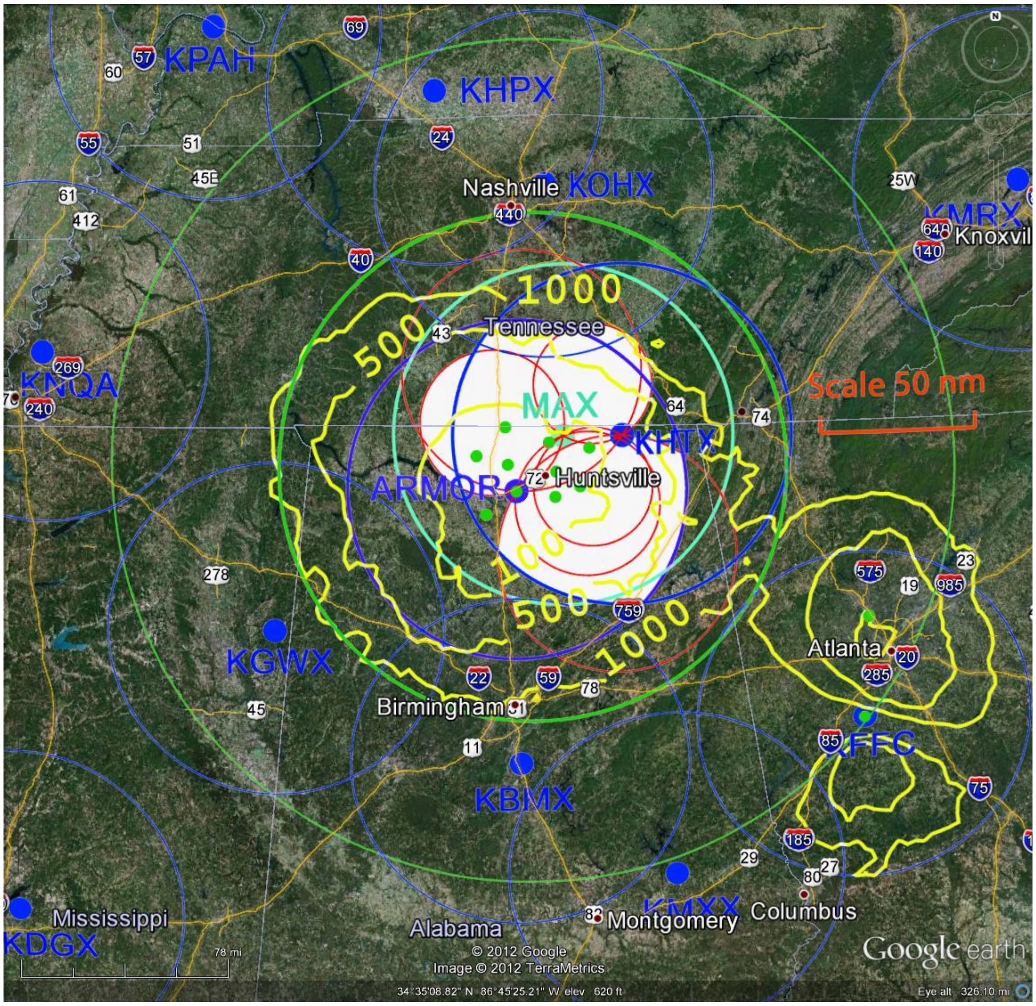


Figure 7-3. DC3 Alabama network configuration. Radar locations are indicated by color-filled circles. The ARMOR (purple) and MAX (light blue) research radars are shown along with the Hytop, AL (KHTX) and several other regional WSR-88D's (blue). Color-coordinated 100 km range rings are shown. Doppler lobes (30° beam crossing angle) between ARMOR-KHTX-MAX are provided (red). The triple-Doppler region, which is the intersection of 100 km range rings and Doppler lobes, is indicated by the white filled area. The LMA sensor locations are indicated by green filled circles, including 11 sensors over northern AL and 2 near Atlanta, GA. LMA height location errors are indicated by yellow contours (100, 500 1000 m). The 150 and 250 km range rings from the NA-LMA network center are given (green). State boundaries, major highways, and major cities are provided for reference.

7.3.1.4 Mobile Integrated Profiling System (MIPS)

The Mobile Integrated Profiling System (MIPS) includes a 915 MHz Doppler wind profiler, X-band profiling radar, microwave profiling radiometer, Lidar ceilometer and a host of standard meteorological sensors. MIPS's home base is sheltered within a berm at the NSSTC building. MIPS routinely obtains boundary layer and precipitation measurements from this location. Prior to the onset of active convection on aircraft mission days, MIPS will be pre-deployed to a favored multi-Doppler lobe (white areas, Fig. 7-3) based on the morning forecast. From inside a Doppler-lobe, MIPS will focus first on characterizing the pre-convective boundary layer, then the convective inflow prior to arrival of convection and finally the vertical column of precipitation as convection moves overhead, which can help constrain the microphysical and kinematic retrievals from the scanning radars.

7.3.2 Research Radar Operations and Scanning

7.3.2.1 Radar Characteristics and Operational Considerations

UAHuntsville owns and operates two dual-polarimetric research radars: ARMOR and MAX (see Section 7.3.1 and Table 7-4 for more details). ARMOR is a C-band, dual-polarimetric radar located at the Huntsville-Decatur International Airport. ARMOR is a collaborative project with WHNT-TV, Huntsville, AL and is used by WHNT in short-term forecasting, including sometimes on-air. ARMOR data is also made available to the NOAA NWS Huntsville WFO for situational awareness and high impact weather now-casting. ARMOR is used for basic and applied research in a number of projects funded by NASA, NOAA, DoD, TVA, and NSF, including continuous mapping of precipitation. Some of these projects will be ongoing and will piggy-back on top of DC3 operations because of their complementary nature. Because of ARMOR's focus on both meteorological and operations research, it scans continuously. If high impact weather is not expected and no other research projects have specific requirements, ARMOR's default scan mode is a three tilt low-level surveillance volume (elevation angles = 0.7°, 1.3°, 2.0) for clear-air boundary layer sampling and precipitation mapping. The ARMOR radar will be operated via remote IRIS display from the DC3 Alabama local operations center, which will be located on the third floor of the NSSTC (National Space Science Technology Center) building on the UAHuntsville campus, which hosts the Department of Atmospheric Science, NASA MSFC Earth Science Office, and the National Weather Service Huntsville Weather Forecast Office (WFO). ARMOR will be operated by a 2 person team to handle radar control, communications and Nowcasting. Imagery and field data will be produced in real-time on the ARMOR data server at NSSTC and uploaded to the DC3 Field Catalog.

MAX is an X-band, dual-polarimetric truck-based mobile radar. The MAX truck cab has room for a 2-3 person team who will similarly accomplish radar control via IRIS display, communications (via Internet chat on cell phone modem), and Nowcasting duties. Like most truck-based mobile radars, MAX's view of storms is obscured in the direction of the truck cab (i.e., "cab block"). MAX's cab block is about 40° in azimuthal width and is up to 10° in elevation. During DC3 multi-Doppler operations, MAX will be deployed from its home base at NSSTC to a fixed site near New Market, AL, which is 42.5 km north-northeast of ARMOR (Fig. 7-3). Deployment to the field site will be based on the daily DC3 forecast and operational status and should take about 1 hour to transit and set up. For a region characterized by ubiquitous trees and rolling terrain, the New Market site, which is around old farmland, has excellent line-of-sight visibility for radar operations in Alabama. Most azimuths have little-to-no partial blocking. A sector from the north-northwest to east-northeast (340° to 60° in azimuth) has sporadic partial blocking up to an elevation angle of 2.5° due to trees. The New Market site allows for the MAX truck cab to be pointed toward the north or the south only due to access considerations. Given all of these factors, the MAX truck cab (and hence cab block) will be oriented toward the north, essentially overlapping with the existing tree partial blockage and mitigating the overall impact. Only a small portion of the northwest ARMOR-MAX dual-

Doppler lobe will be impacted by blockage. In the event that chat communications are lost between the DC3 Operations Center and the DC-8 or G-V aircraft over the Alabama domain, the MAX radar will be equipped with a ground-to-air radio for communications. Radar imagery will be generated at MAX and uploaded to the Field Catalog in real-time via cell phone modem. MAX field data will be processed in real-time but uploaded to the Field Catalog at the end of operations due to bandwidth limitations.

Table 7-4. UAHuntsville research radar specifications.

Radar Characteristic	ARMOR (C-band)	MAX (X-band)
Location	Huntsville Intl. Airport	Mobile (truck-based)
Transmit frequency	5625 MHz (magnetron)	9450 MHz (magnetron)
Peak Power	350 kW	250 kW
Pulse width	0.4, 0.8, 1.0, 2.0 μs	0.4, 0.8, 1.0, 2.0 μs
PRF Range	250-2000 Hz	250-2000 Hz
Antenna diameter/beamwidth	3.7 m/1.0° (Center-fed parabolic, CF-P)	2.44 m/0.95° (CF-P)
Max (typical) rotation rate	24° s^{-1} (18-21° s^{-1})	24° s^{-1} (18-21° s^{-1})
First side-lobe	-30 dB	-31 dB
Polarization mode (H+V)	Simultaneous Transmit and Receive (STaR)	STaR
Signal Processor, Controller	Vaisala-Sigmet (V-S) RVP/8, RCP/8	V-S RVP/8, RCP/8
Variables	Z_h, V_r, σ, Z_{dr}, Φ_{dp}/K_{dp}, ρ_{HV}	Z_h, V_r, σ, Z_{dr}, Φ_{dp}/K_{dp}, ρ_{HV}

The ARMOR and MAX radars operate in Simultaneous Transmit and Receive (STaR) polarization mode. Recorded dual-polarimetric moments include: horizontal reflectivity (Z_h), radial velocity (V_r), spectral width (σ), differential reflectivity (Z_{dr}), differential phase (Φ_{dp}) and correlation coefficient (ρ_{HV}). For quality dual-polarimetric measurements in STaR mode, UAHuntsville typically employs 56 to 64 samples in research operations. The radar pulse width is selectable (Table 1) but is typically set at 0.8 μs. The beam width of each radar is approximately 1°. The maximum rotation rate is 24° s^{-1} while typical rotation rates range from 18 to 21° s^{-1}. A summary of the technical specifications for the ARMOR and MAX radars can be found in Table 7-4.

Radar control, processing and display are accomplished using the Vaisala-Sigmet RVP/8, RCP/8 and the Interactive Radar Information System (IRIS). IRIS supports both Plan Position Indicator (PPI) (i.e., fixed elevation angle and varying azimuth angle) and Range Height Indicator (RHI) (i.e., fixed azimuth angle and varying elevation angle) scan modes for emphasizing horizontal or vertical sampling, respectively. Using IRIS, any number of radar scan parameters (e.g., rotation rate, sample number, gate spacing, pulse width, pulse repetition frequency, azimuthal resolution, elevation angle list or limits, azimuthal angle list or limits, maximum range, maximum velocity) can be varied for each radar task (i.e., set of scan sequences such as a PPI sector volume) as needed by the radar operator. Multiple radar tasks can be scheduled together to repeat continuously or on the system clock, which is convenient for time synching of multi-Doppler radar operations. Radar products, including field data (IRIS RAW format) and imagery of any PPI or RHI scan, can be produced and archived by the IRIS system. Imagery for both radars will be produced and uploaded to the Field Catalog in real time. Before uploading to the Field Catalog, radar field data will be converted from IRIS RAW to NCAR DORADE sweep (SWP) file format using an automated shell script that call radar data translators on an NSSTC server in real time for ARMOR and at the end of the operations day for MAX due to bandwidth limitations.

7.3.2.2 Radar Scanning

During pre-convective operations, ARMOR and MAX will monitor the boundary layer with repeating low-level surveillance scans (e.g., elevation angles of 0.7° to 2.0°). Since ARMOR runs continuously to satisfy a variety of science and operational objectives, ARMOR will be implementing these surveillance scans continuously when not in DC3 convective scan mode. Based on the morning forecast MAX will deploy from its home base at NSSTC to its multi-Doppler site near New Market, AL (Fig. 7-3) prior to the onset of convection. Once setup at New Market, MAX will begin low-level surveillance scans.

During DC3 operations periods with active convection or remnant anvils, ARMOR and MAX radar will scan in time synchronized PPI sector volumes (SV's) with a 12 minute repeat cycle of the scan tasks (Fig. 7-4). The number of SV's completed (2 to 5) during each 12 minute cycle will depend on the horizontal and vertical extent of storms and location of the storms relative to the radars. At the end of the SV task sequence, the ARMOR radar will conduct a RAIN1 (RN1) low-level surveillance scan (elevation angles: 0.7°, 1.3°, 2.0°) while the MAX will implement Range Height Indicator (RHI) scans through regions of interest (e.g., convective core, anvil) near the DC-8 and G-V aircraft when present. The ARMOR RN1 surveillance scan will provide a regular update of convective activity in the DC3 region and will satisfy other non-DC3 science and operational requirements. The MAX RHI's will provide enhanced vertical resolution and structure information in key storm regions for DC3 science and operations. The overall 12 minute synchronized scan sequence will then be repeated until the end of DC3 operations.

To facilitate time synchronization between ARMOR and MAX, the maximum length of time (M:SS; where M=minutes and SS=seconds) required for a SV of either radar will be grouped into four scan categories (I. 2:00, II. 2:30, III. 3:20, and IV. 5:00) such that SV's in each category will take between I. 1:30 and 2:00, I. 2:00 and 2:30, II. 2:30 and 3:20, III. 3:20 and 5:00 and be associated with a fixed number of SV's (I. 5 SV's, II. 4 SV's, III. 3 SV's, IV. 2 SV's) during the 12 minute repeat cycle. Both ARMOR and MAX will operate in the same scan category (I – IV). The radar with the longest SV time needed to sample the horizontal and vertical extent of anvil cloud and parent convection will dictate the scan category. Within a scan category, the SV# for ARMOR and MAX will start at the same time during the 12 minute cycle, thus re-synching the radars at the start of each SV.

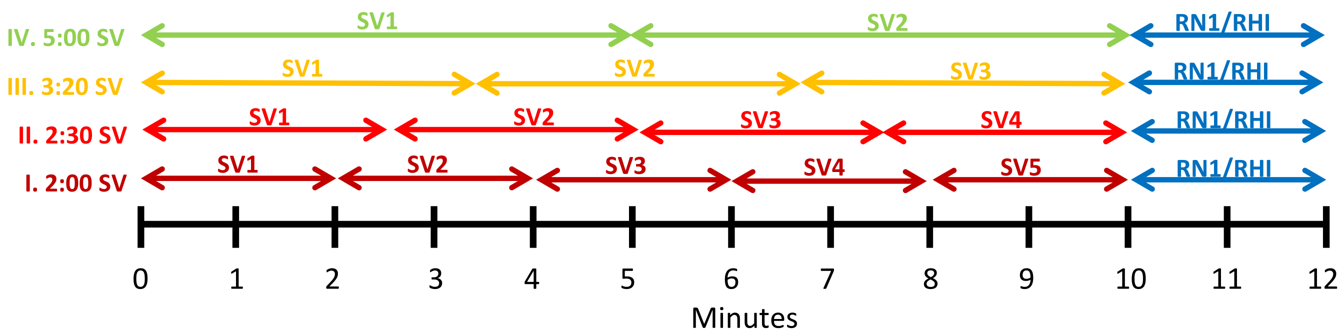


Figure 7-4. Timing of AL convective scan strategy. Key: SV=Sector Volume, RN1=RAIN1 Surveillance Scan; RHI=Range Height Indicator. ARMOR and MAX will operate in time synchronized SV's over a 12 minute repeating pattern, which ends with a RN1 (RHI) scan sequence for ARMOR (MAX) during the final two minutes. The number of SV's that can be accomplished in a 12 minute period will depend on storm conditions. Based on the required maximum SV scan time of both radars, a scan category (I – IV) will be selected. The maximum SV time (M:SS) for each category is shown to the left. Both radars will run the same scan category sequence and will be synchronized at the start of each SV#.

The intent of the convective scan strategy in Fig. 7-4 is to sample the full horizontal and vertical extent of the anvil cloud flown by the aircraft and associated parent convection while maintaining excellent data quality, radar scan synchronization, temporal resolution and spatial resolution for multi-Doppler and dual-polarimetric retrievals. Larger, taller and closer storms will necessitate longer sector volume times, moving upward from 2 (red) to 5 minutes (green) in Fig. 7-4. Storm coverage and radar data quality will be maintained with the scan settings highlighted in Table 7-5. The PPI SV elevation angle stepping in Table 7-5 is designed to maintain better than 1 km vertical resolution at 50 km range. Some convection and anvil in the radar cone of silence will likely not be sampled (e.g., α_{max} = 27° reaches 11.4 km above radar level at 25 km range).

Table 7-5. ARMOR and MAX scan parameters.

Scan Parameter Name (Symbol)	Scan Parameter Value
Sample or Pulse Number (N)	56-64 (STaR mode)
Pulse Width (τ)	0.8 μs
PPI/RHI (Surveillance) Gate Spacing (Δr)	125 m (250 m)
Pulse Repetition Frequency (PRF)	1200 Hz
Maximum Unambiguous Range (R_{max}) Maximum Unambiguous Velocity (V_{max})	124.9 km ARMOR: 15.9 m s^{-1}; MAX: 9.5 m s^{-1}
PPI Scan Rate ($d\phi/dt$) / RHI Scan Rate ($d\alpha/dt$)	18-21° s^{-1} / 2-4° s^{-1}
PPI Azimuthal Spacing ($\Delta\phi$) RHI Elevational Spacing ($\Delta\alpha$)	≈ 1.0° (controlled by N, PRF, $d\phi/dt$) ≈ 0.2° (controlled by N, PRF, $d\alpha/dt$)
PPI Sector Width (Φ) RHI Sector Width (A)	120° to 180° 15° to 45°
PPI Sector Volume Elevation Angle List (α, °) (number of elevation angles in PPI Sector Volume will vary depending on conditions)	0.7, 1.9, 3.0, 4.1, 5.3, 6.4, 7.6, 8.7, 9.8, 11.0, 12.1, 13.2, 14.3, 15.4, 16.5, 17.6, 18.7, 19.8, 20.9, 22.0, 23.1, 24.3, 25.6, 27.0

7.4 Radiosonde Deployment Strategy

The goal of the DC3 sounding program is to provide soundings for documenting the pre-storm, storm inflow and post storm environments of storms targeted by DC3. Mobile radiosonde resources are available to DC3 in the Alabama, Colorado and Oklahoma-West Texas venues. Approximately 60 radiosonde flights have been budgeted in each of the DC3 regions. Radiosonde flights will occur on DC3 aircraft days, as well as on non-aircraft days.

<u>Mode of operation for a DC3 aircraft day</u>

A DC3 aircraft day is defined as a day when the DC3 research aircraft target weather in one of the three DC3 study regions. In rare cases, on a given day the DC3 aircraft may target storms in two of the three DC3 study regions (CO and OK, or OK and AL). The “DC3 aircraft day” mode of operation refers specifically to any given venue(s) in which the aircraft are operating.

On an aircraft day, up to 2 pre-storm soundings will be taken starting at 2-3 hours prior to the time of expected convective initiation (CI). These pre-storm soundings will be taken to characterize the environmental wind, temperature, and humidity profiles, prior to CI. The time between launches will nominally be 1.5 hours to assure that full tropospheric depth soundings are obtained. The location of the pre-storm soundings should be chosen such that this location can also be used for the first 1-2 storm inflow soundings to characterize the inflow air feeding the storm. Typically, pre-storm soundings will commence at 15-16 UTC in Alabama and around 18 Z in Colorado and Oklahoma. A total of 3-4 storm inflow radiosondes should be launched at a nominal spacing of 1.5 hours. One post-storm sounding should also be obtained after the storm has exited the region or decayed. The location of the pre-storm, inflow, and post-storm soundings should be decided by the local radiosonde and radar network scientists, with input from the Operations Center in Salina and local venue nowcaster.

Based on this schedule, DC3 expects to use a total of ~6 radiosondes per aircraft day, per study region. Approximately 4-6 aircraft days will be carried out in a given study region so 24-36 of the available 60 radiosondes will be committed to aircraft days. Thus, approximately 60% of the available regional radiosondes will be expended on DC3 aircraft days, with the remaining 40% used on DC3 non-aircraft days.

Each of the three DC3 study regions should identify several locations that could be used for the pre-storm and inflow soundings to facilitate decision-making. Ideally these locations should also be in the range of 40-75 km from where storms are expected to develop. The NE Colorado default sounding location is Ft. Morgan. Northern Alabama is the NSSTC building parking lot. Central & Southwest Oklahoma and West Texas is…

<u>Mode of operation for a non-aircraft day</u>

DC3 radiosondes may also be needed in a particular region even when aircraft are not slated to fly in that region on a given day. These so-called “non-aircraft days” are meant to provide additional ground based data on storms of interest to DC3 or to satisfy specific science objectives for the PI’s from that venue. On non-aircraft days, the local radiosonde and radar network scientists will dictate the number of radiosondes to be launched, as well as when and where the sondes are launched. At least two radiosondes will be launched, one to characterize the pre-storm environment and one to characterize the storm inflow conditions. However, as many as 6 radiosondes may be launched, following the protocol of the aircraft day sounding operations. Assuming a total of ten (10) operating days (i.e., combining aircraft and non-aircraft days) and also assuming four (4) aircraft days and 6 soundings per day, approximately 6 non-aircraft missions can be supported in each location.

Profiler and radiosonde operations

NCAR can make available their MISS and the MGAUS systems. MISS includes a 915 MHz profiler and a radiosonde unit. MGAUS is a highly mobile radiosonde unit. It is desirable on Colorado DC3 aircraft days that MISS is deployed to provide continuous (profiler-observed) winds and up to two pre-storm soundings. The MGAUS will then deploy to locations for the storm inflow and post storm soundings. In Alabama, MIPS (consisting of a 915 MHz profiler system) will be deployed within a dual-Doppler lobe. A mobile radiosonde unit will then provide the requisite soundings for DC3. Mobile environmental radiosondes in the Oklahoma-Texas venue will not be accompanied by mobile, or semi-mobile profiler observations. However, the greater central Oklahoma region is instrumented with several fixed profilers at the following locations: the ARM Central Facility; a complement composed of an AERI, an MWR, and a Doppler wind lidar on the Norman National Weather Center roof co-located with the operational radiosonde site (OUN); and the University of Wisconsin's aerosol lidar at Max Westheimer Airport in Norman.

8. Satellite Data

Several observations from satellite platforms will be used for DC3 planning and analysis. Among the large number of observations, a few will receive focus. GOES infrared and visible images will be updated every 15 minutes and daily maps of OMI NO_2 columns will be available. Other satellite products such as OMI CH_2O and AIRS water vapor, CO, and O_3 will be included in the DC3 dataset and used for post-analysis.

8.1 Satellite Products

8.1.1 Near Real-time data

OMI (Aura) tropospheric NO_2 column – 1430 overpass, data 1900 CDT at earliest. Standard product plus special lightning/convective outflow product with pollution signal removed, assumed NO_2 profile has upper tropospheric maximum.

GOME-2 (MetOp-A) tropospheric NO_2 column – 1030 overpass, 1130 CDT data. Orbits about every 90 minutes.

MOPITT CO – morning and evening overpasses. Data from prior day available by 0430 CDT. Plots for several selected levels.

8.1.2 Data available at longer times

IASI CO (MetOP-A) – morning and evening overpasses. Possible additional day delay in getting plots. Plots for several selected levels.

9. Forecasting, Nowcasting, and Modeling

Several forecasting, modeling and operational observation products will be used for assessing the weather and making decisions regarding aircraft operations. Those products that are archived on the Field Catalog are:

- Several satellite channels from GOES-13
- Upper Air analysis at several pressure levels
- Tropopause height
- Skew-T diagrams at many locations and COSMIC interactive soundings
- Wind profiler diagrams at several locations
- Surface station reports for each DC3 sampling region
- Lightning flashes from the Oklahoma LMA, the USPLN, and the NLDN
- Stage IV NCEP precipitation (6-hourly and hourly)
- Stage II NCEP daily precipitation
- NEXRAD composite radar reflectivity for Rocky Mountains to Appalachians
- NEXRAD mosaic radar reflectivity for contiguous U.S.
- NSSL Q2 composite reflectivity for Rocky Mountains to Appalachians
- NEXRAD composite radar reflectivity from several locations
- NCAR WRF ARW Forecast Products: low-level shear, CAPE, CIN, mean sea level pressure, precipitation mixing ratio, reflectivity, forecasts at 850, 700, 500, 300 hPa, soundings at several locations, and tracer forecasts
- NSSL WRF Forecast Products: precipitation, reflectivity, dew point, temperature, maximum downdraft, maximum updraft, maximum updraft helicity, most unstable CAPE
- TTU WRF Forecast Products: (both dx=12km and dx=2km runs) forecasts at 850, 700, 500 hPa, CAPE, LCL, radar reflectivity, …. Soundings at AMA, FDR, LBB, MAF.
- Plan to have forecasts from CAPS (WRF NMM, WRF ARW, and Ensemble) forecasts.
- NCEP GFS Forecast Products: surface, 850, 700, 500, 300, 250, and 200 hPa forecasts, 6-hr precipitation
- NCEP NAM Forecast Products: surface, 850, 700, 500, 300 and 200 hPa forecasts, 6-hr precipitation, radar reflectivity
- NCEP RUC Forecast Products: surface, 850, 700, 500, 300 and 200 hPa forecasts, 1-hr precipitation, CAPE, CIN, and helicity
- ESRL High Resolution Rapid Refresh RUC Forecast Products: low and mid-level shear, 1-hr precipitation, surface temperature, CAPE, CIN, reflectivity, maximum updraft helicity, and most unstable CAPE

9.1 Forecasting and Nowcasting

Weather forecasting discussions during the DC3 field campaign will occur every day. The daily schedules are described in Section 2. There will be a weather discussion during the DC3 Daily Planning Meeting each morning, a pilot weather briefing 1-2 hours before take-off, and an afternoon weather update during the post-flight meeting or in the mid-afternoon on non-flight days. During flight days, especially flights that sample active convection, nowcasting will occur during the time period from the end of the morning planning meeting to near the end of the flight.

There are 5 special modeling tools that will be used during DC3 to make weather, tracer, and chemical forecasts. In addition, products from several operational models will also be used for making weather forecasts. These special tools are summarized in Table 9-1 and described further below.

Table 9-1. Summary of modeling tools that will be employed during DC3.

Name	Run time	Update time	Time available to community	Observations used
3 km WRF-ARW Weather & tracer forecasts	2 48-hr sims run daily	00Z 12Z	13Z = 0800 CDT 01Z = 2000 CDT	
3 km WRF TTU Weather forecasts	4 60-hr sims run daily	00Z, 06Z, 12Z, 18Z	10-13Z = 0500-0800 CDT	
4 km WRF NSSL Weather forecasts	1 36-hr sim run daily	00Z		
FLEXPART Particle dispersion model Trajectory forecasts in UT	1 48-hr run after flight completes	~02Z		Aircraft lat & lon GFS winds
0.5x0.6° MOZART Chemical forecasts	1 5-day run	00Z	14Z = 0900 CDT	

9.1.1 Daily Weather Briefing

The Daily Weather Briefing (see Section 2.2) will last for a maximum of 30 minutes. The overall goals of the briefing are to offer the DC3 PIs and the rest of the decision-making team guidance on:

- the expected character of convection within the three DC3 domain foci for the current day and several days beyond
- the expected location of aged outflow from the previous day’s storm study (if any)

Three basic forecast-based decisions/issues will be considered as a result of our weather briefing:

1. Should DC3 aircraft conduct storm studies or aged outflow studies today?
2. When and where should future storm studies be conducted?
3. Will the upper tropospheric aged outflow from today’s studied convection be reachable and studyable tomorrow?

There are several considerations and limitations for DC3 aircraft deployments. These are discussed in Section 3.3.

Specific forecasting questions to consider:

1. Will there be convection within the given regional domains today?
2. When will the convection initiate?

3. How strong/deep will the convection be (max updrafts, cloud tops, anvil height and depth, etc.)?
4. What will be the anticipated storm motion?
5. What will be the anticipated low-level storm-relative inflow and anvil outflow?
6. What will be the primary convective mode at onset (e.g., isolated, scattered, supercellular, squall line)?
7. How will the convective mode evolve during the observation period (e.g., isolated cells growing upscale into squall line…. etc.)? Which direction will it move?
8. Where will the convection and/or convective outflows be located the following day?
9. What is the potential for lightning?
10. What are the projections for aircraft turbulence?
11. What is the anticipated height of the tropopause?
12. What severe weather could be expected at the Operations Base?

The briefing commences with a 10 min larger-scale overview of the current and projected weather over the central U.S. (from the Rockies to Appalachians). This will include satellite and radar loops to highlight existing convective activity, discussion of larger-scale forcing features likely to influence the day's and next several day's weather, and a discussion of general model guidance (both operational and experimental high resolution) for potential convective activity. This discussion will be led by the DC3 Lead Forecaster, who will also provide a one paragraph summary for inclusion in the Field Catalog.

Following the weather overview, the briefing then proceeds to a more detailed discussion of the probability of convection within the three DC3 domain foci. This discussion is led by the various regional forecast leads, and highlights the local/mesoscale aspects of the forecast, emphasizing more specific information as to the timing and anticipated character of the convection in that particular region on the current day. Specific products include observed and projected thermodynamic profiles (SkewTs), output from locally run high-resolution models, anticipated storm (anvil) heights, storm motions, storm-relative wind profiles, and the like. The discussion concludes with a brief summary of the local forecast for the next day as well. Each region is allocated 5 min for their individual briefings, but this may be adjusted to account for more or less active weather within specific regions.

To aid in this discussion, each region will be asked to provide a graphical probability timeline for convection for the next 42 hours (see sample in Figure 9-1), along with a brief written discussion (1 paragraph), for inclusion in the Field Catalog. The main points of the Daily Weather Briefing will be summarized during the Daily Planning meeting (see section 2.3).

9.1.2 Tracer Forecasts

The Daily Weather Briefing finishes with a 5 min discussion by the Lead Tracer Forecaster of the projected tracer transport from the day's anticipated convection (if any). The tracer forecast includes information on the long-range transport of CO, O_3, and tracers to provide context of the composition of the troposphere. This is summarized in the Daily Planning Meeting.

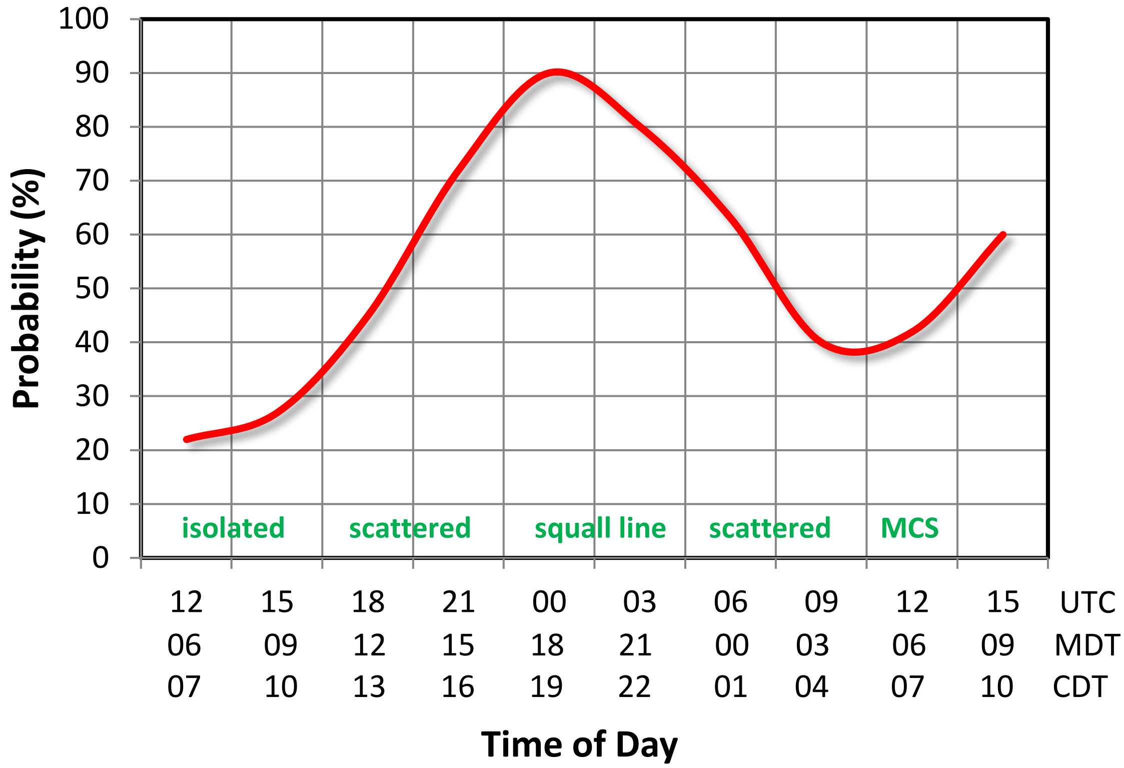


Figure 9-1. Probability timeline example provided by each regional forecast team to aid aircraft deployment decision making.

9.1.3 Forecast Team Staffing Schedule

Forecasting and nowcasting efforts will be coordinated and overseen by the DC3 Lead Forecaster, located at the Operations Center in Salina. The Lead Forecaster's duty day will generally commence a couple of hours prior to the morning briefing, and continue through the afternoon Weather Forecast Update.

Each venue (Colorado, Oklahoma and Alabama) is also asked to supply focused forecasting support for their location each day, and is expected to contribute to the Daily Weather Briefing, as described above. The venue forecaster can be located either at the home center or at the Operations Base in Salina.

A minimum of 3 nowcasters is needed at the OPS Base in Salina on operational days to help guide the various aircraft and any relevant ground crews.

A nowcaster is assigned to each of the relevant facilities (e.g. GV, DC8, ground crews, etc.) to help foster good communications, coordination and safety for the various teams, and to offer direct input/feedback to the decision making process.

It is anticipated that the nowcasting duty day for aircraft support commences a couple of hours prior to aircraft takeoff, and continue until aircraft landing. The nowcasting duty day for ground crew support generally begins once ground crews are on the road (for mobile units), or an hour prior to anticipated aircraft operations, and continue until the end of ground operations.

9.1.4 Flight Operations Nowcasting

Before and during DC3 flight operations, there is a need for real-time updates of existing and changing weather conditions and short-term forecasts, including projections of tracer locations, severe weather in the vicinity of aircraft operations, terminal weather updates, etc.

Specific duties of the Nowcaster:

1) Prior to aircraft operations and during ferry, update on-board Mission Scientist and Mission Coordinator, and ground-based Operations Director on the evolving weather scenario, including expected timing and location of convective initiation.
2) During flights, monitor evolving convection, including storm intensity, motion, storm-relative winds, lightning activity, cloud/anvil tops, etc. This includes closely monitoring the target storm once a target has been chosen, as well as nearby storms that could impact ongoing observations or that might be targeted subsequently.
3) Specific to sampling in the Oklahoma region where mobile radars will be deployed, the nowcasting should begin as soon as the radars depart from the Oklahoma operations base.

9.1.5 Terminal Forecasts and Severe Weather Updates

Forecasts and nowcasts are also produced for the region around Salina to help with decision-making in deploying the aircraft and returning the aircraft to the Operations Base (see Section 3.3.4). Of particular interest is the occurrence of severe weather that could prevent takeoff or landing, damage the DC-8 which is located outside of a hangar, or require evacuation of the GV and Falcon. Severe weather at potential alternate airports is also monitored to advise the pilots on the best course of action should they need to be used.

9.2 Modeling

9.2.1 Operational Model Output and Products

Standard operational models (GFS, NAM, RUC) provide various products that are archived on the DC3 Field Catalog (see list in Section 9.1).

9.2.2 Special High Resolution Regional & Mesoscale Models

Real-time 3 km WRF-ARW Forecasts

One of the special tools available for DC3 forecasting is 48 h, 3 km horizontal grid resolution forecasts using explicit convection, supplied by WRF-ARW. Forecasts are run at both 00 UTC and 12 UTC. The suite of model physics includes the Noah land surface model, MYJ PBL, Morrison microphysics, and the RRTMG radiation scheme. In addition, passive boundary layer tracers are included for the full domain as well as the three specific DC3 domains, to help track and project convective transport. Lightning flash rates are estimated from parameterization schemes based on storm variables and used to compute a lightning NO_x tracer that is transported in the model.

Initial and boundary conditions for daily forecasts are drawn from an ensemble data assimilation system using NCAR's DART (Data Assimilation Research Testbed) system. DART is an open-source community facility for ensemble data assimilation developed and maintained by the Data Assimilation Research Section at NCAR.

WRF-DART is used in a continuously cycling mode assimilating METAR, marine, ACARS, satellite winds, GPS occultation, and radiosonde observations.

A 50 member ensemble provides a set of CONUS mesoscale (15 km horizontal resolution) analyses every six hours over the duration of the forecast period. Daily at 00 UTC and 12 UTC, a single analysis is selected from the ensemble to make a 48 hour convection resolving (3 km horizontal resolution) forecast for an eastern 2/3rds CONUS region.

WRF TTU high-resolution runs for Oklahoma and Texas:

The GFS-initialized deterministic runs are conducted at 12 and 3 km grid resolution, on a slightly expanded OK-TX domain to reduce influence of the boundaries. These are run four times daily to 60 hrs, with the 06Z forecast run appearing between 10Z and 13Z. (http://www.atmo.ttu.edu/bancell/real_time_WRF/ttuwrfhome.php)

By the end of March, a 50 member EnKF run (using DART) are also available. These are at 12 km on the same domain as the deterministic runs. There is also an outer 36 km domain covering the US plus the Pacific basin to near Japan. It assimilates surface and ship observations, cloud track winds, ACARS, and upper air data. Runs begin every six hours. For the 12Z run, tests indicate a 48 hour forecast of all ensemble members will be complete by 16Z.

It is possible to have some 3 km downscaled runs based on ensemble members ready by 1 May, but that's probably too uncertain for the DC3 planning timeline.

WRF NSSL 4 km Simulations

The forecasters from Alabama primarily use the WRF NSSL forecast. The WRF model (v3.1.1) is run daily using an initialization time of 00 UTC and forecast length of 36 hours. The initial and boundary conditions are obtained from interpolation of the routinely available 40km NAM Model fields obtained from EMC/NCEP, using the WRF Preprocessing System (WPS). The grid spacing is 4 km (1200x800 grid points). There are 35 vertical levels. A time step of 24 s is used.

The WRF model is configured with the MYJ BL/turbulence parameterization, WSM6 microphysics, RRTM longwave radiation, Dudhia shortwave radiation, Noah land-surface model, positive definite advection of moisture.

9.2.3 Special High Resolution Chemistry & Tracer Models

FLEXPART Particle Dispersion Model

An interactive webpage allows the FLEXPART particle dispersion model to be run soon after the completion of each flight through active anvils (run with half-degree GFS winds updated 4 times per day). A passive tracer is released from the anvil-related portion of the flight track to predict where the decaying anvil will be located over the next 48 hours. The forecast tracer position along with near real-time GOES satellite images (visible, IR and water vapor), will be used to track the position of the decaying anvil. These products will be available for the entire duration of DC3.

MOZART-4 Chemical Tracer Forecasts

MOZART-4 will be run in forecast mode with a number of artificial tracers. The driving meteorology will be from GEOS5, and the horizontal resolution will be 0.5x0.6 deg. 5-day forecasts, initialized at 0Z, will be available each day by 14Z. CO-like tracers will be initialized from emissions of anthropogenic pollution and wildfires in local, western US, Asia, and other regions. A lightning NOx tracer and a biogenic isoprene-like tracer will be included.

10. Data and Information Management (WG)

10.1 Introduction

The development and maintenance of a comprehensive and accurate data archive is a critical step in meeting the scientific objectives of DC3. The overall guiding philosophy for the DC3 data management is to make the completed data set available to the scientific community as soon as possible following the DC3 Field Phase, while providing ample time to the DC3 Investigators and Participants to process, quality control, and analyze their data before providing open access. DC3 will coordinate closely with the SEAC4RS Project in the archival and exchange of data and associated information.

The DC3 data will be available to the scientific community through a number of designated distributed DC3 Data Archive Centers (DDACs) coordinated by the NCAR/EOL. This includes the main archive at EOL but also includes (but not limited to) main archives at NASA, NOAA, and DLR. The EOL coordination activities fall into three major areas: (1) determine the data requirements of the DC3 scientific community and develop them into a comprehensive DC3 Data Management Plan through input received from the DC3 Scientific Steering Committee (SSC), DC3 Data Management Working Group (DMWG), project participants, and other tools such as the data questionnaire; (2) development and implementation of an on-line Field Catalog to provide in-field support and project summaries/updates for the Principal Investigators (PIs) and project participants to insure optimum data collection; and (3) establishment of a coordinated distributed archive system and providing data access/support of both research and operational data sets for the DC3 PIs and the scientific community. To accomplish these goals, EOL will also be responsible for the establishment and maintenance of the DC3 Data Management Portal. These web pages provide "one-stop" access to all distributed DC3 data sets, documentation, on-line Field Catalog products, collaborating project data archives, and other relevant data links. EOL will make arrangements to ensure that "orphan" data sets (i.e. smaller regional and local networks) will be archived and made available through the DC3 archive. EOL may also quality control and reformat selected operational data sets (e.g. atmospheric soundings or surface data) prior to access by the community as well as prepare special products or “composited” data sets (see Section 10.5.1).

Oversight of the DC3 data management tasks will come from the DC3 DMWG (see Section 10.3 for detailed DMWG responsibilities), Principal Investigators, and other participating agencies and groups.

10.2 Data Policy

In general, users will have free and open access to all the DC3 data, subject to procedures to be put into place at the various DDACs. DC3 will also coordinate closely and be as consistent as possible with the Data Policy and protocol enacted for SEAC4RS since these projects are closely related, collaborative, and sequential. The following is a summary of the DC3 Data Management Policy by which all DC3 participants, data providers, and data users are requested to abide by:

- All investigators participating in DC3 agree to promptly submit their quality-controlled data to the appropriate DDAC to facilitate intercomparison of results, quality control checks and inter-calibrations, as well as an integrated interpretation of the combined data set.
    - Standard operational meteorological data such as synoptic observations, special rawinsonde observations, and satellite imagery shall be submitted to the appropriate DDAC within six months following the end of the DC3 field campaign (**available by December 2012**).
    - Research datasets such as PI instrument data and other special observations requiring additional post-processing shall be submitted to the appropriate DDAC no later than **1 April 2013**. Exemptions may be granted on an individual case-by-case basis by Program Managers and Project Management.
- It is recognized that some complete datasets may not be entirely available until over 12 months following the end of the SEAC4RS field collection. However, it is anticipated that the highest priority cases will be processed first and be available within one year of the completion of the SEAC4RS field program. Therefore, the data analysis period is defined as 12 months following the end of the SEAC4RS field collection. During this 12-month period, the DC3 investigators shall have exclusive access to the data. This data analysis period is defined to accommodate the amount of processing required for all data products, to provide an opportunity to quality control the combined data set, and to provide the investigators ample time to publish their results. Data providers have the option to restrict (or password protect) their datasets for part or all of the data analysis period.
- During the data analysis period, the investigator(s) who collected the special data sets must be notified first of any intent to use the data. In particular, this applies if data are to be provided to other parties via journal articles, presentations, and research proposals. It is expected that for any use of the DC3 data investigators responsible for acquisition of data will be invited to become collaborators and co-authors on any projects, publications and presentations. If the contribution of the data product is significant to the publication, the DC3 investigator responsible for generating a measurement or a data product should be offered the right of co-authorship or collaboration at the discretion of the investigator who collected the data. Any use of the data should include an acknowledgment (i.e., citation). In all

circumstances, the DC3 investigator or data source responsible for acquisition of data must be acknowledged appropriately.

- All data shall be promptly provided to other DC3 investigators upon request. All DC3 investigators will have equal access to all data. A list of DC3 investigators will be maintained by the DC3 Project Office and will include the investigators directly participating in the field experiment as well as collaborating scientists who have provided guidance in the planning and analysis of DC3 data. No data may be provided to a third party via journal articles, presentations, or research proposals without the consent of the investigator who collected or is responsible for the data.
- Following the end of the initial data analysis period, all data shall be considered in the public domain (**no later than 1 October 2013**). A data set within the DC3 archive can be opened to the public domain earlier at the discretion of the data provider for this particular data set.
- All acknowledgments of DC3 data and resources should identify: (1) DC3; (2) The providers who collected the particular datasets being used in the study; (3) The relevant funding agencies associated with the collection of the data being studied, and (4) the role of EOL or relevant data archive center.

It is anticipated that four types of data that will be submitted from aircraft and ground observations. Similar data will be submitted from the output of forecasting and analysis models, satellite instruments, and other observing systems. These deadlines are consistent between DC3 and SEAC4RS investigators since many are participating in both projects.

1) Field data – quick turnaround data (<24 hours) with preliminary calibration factors;
2) Preliminary data submitted to the archive less than six months after the SEAC4RS campaign completion (1 April 2013 or earlier);
3) Final data submitted 9-12 months after the end of the campaign (1 October 2013); and
4) Comparison data submitted as described above but treated separately to enable blind comparisons. A DC3 Comparison Referee will be selected who will process the comparison data according to procedures developed by the DMWG, and present them to the DC3 Science Team. This analysis and presentation will be done quickly (particularly for field data) to help instrument PIs detect problems they may have with their instruments or data reduction procedures.

10.3 Data Management Working Group

Oversight of the DC3 data management tasks will come from a designated DC3 Data Management Working Group (DMWG) in collaboration with the DC3 Scientific Steering Committee. The DMWG will have the primary responsibility to develop the DC3 Data Management Plan. This document will contain details of the strategic and tactical data management implementation such as: (1) describing data policies and protocol, data compilation (including special data sets) and attribution; (2) providing details of the DC3 data archive system and data submission/access; (3) identifying the sources of observations from existing and planned networks; and (4) providing details and assisting in the developing integrated data sets from existing observational systems and operational model output. The DMWG will also collaborate closely with other DC3 related programs such as SEAC4RS and other related regional projects.

The first step in organizing the DC3 data management support is to determine what data are required from the various scientific components of the program. EOL has developed and distributed a data questionnaire to survey the DC3 participants to document this information. This questionnaire information with input from other data sources, DC3 Investigators, and sample data sets will be used to obtain detailed information regarding the various data sets (e.g. data format, data set size, data frequency and resolution, real-time operational requirements, etc.). This will assist the DMWG (and the collaborating DDACs) in handling and processing the data as well as developing any format converters necessary. The PIs (and data providers) will be requested to adequately document data sets in accordance with metadata standards agreed upon by the DMWG and summarized in the Data Management Plan.

10.4 Real-Time Data

10.4.1 DC3 Field Catalog

NCAR/EOL will implement and maintain a web-based DC3 on-line Field Catalog that will be operational during the DC3 field phase to support the field operational planning, product display, and documentation (e.g. facility status, daily operations summaries, weather forecasts, and mission reports) as well as provide a project summary and "browse" tool for use by researchers in the post-field analysis phase. Data collection products (both operational and research) will be ingested into the catalog in near real time beginning **the week of 23 April 2012**. The Field Catalog will permit data entry (data collection details, field summary notes, certain operational data etc.), data browsing (listings, plots) and limited catalog information distribution. A Daily Operations Summary will be prepared and contain information regarding operations (aircraft flight times, major instrument systems sampling times, weather forecasts and synopses, etc.). These summaries will be entered into the Field Catalog either electronically (via a web interface and/or e-mail) or manually. It is important and desirable for the PIs to contribute product graphics (e.g., plots in gif, jpg, png, or pdf format) and/or preliminary data to the Field Catalog whenever possible. Although the Field Catalog will be publically available, access to preliminary data will be restricted to project participants only. Updates of the status of data collection and instrumentation (on a daily basis or more often depending on the platforms and other operational requirements) will be available. Public access to the on-line Field Catalog is located at: http://catalog.eol.ucar.edu/dc3/ . The Field Data Catalog User's Guide (with specific instructions for submitting reports and data products) is located at: http://catalog.eol.ucar.edu/documentation/ .

EOL will monitor and maintain the field catalog through the duration of the field deployment and also provide in-field support and training to DC3 project participants. Following the DC3 field phase, this Field Catalog will continue to be available on-line (as part of the long-term archive) to assist researchers with access to project products, summaries, information, and documentation. Preliminary data will not be retained as part of the Field Catalog, but final data will be submitted and available through the DC3 archive.

10.4.2 Field Catalog Components, Services and Related Displays

The field catalog will be the central web site for all activities related to the field campaign. As such it will contain products and reports related to project operations as well as forms for entering/editing reports, uploading new products, data files, photos or reports. The field catalog will also provide a preliminary data sharing area, a missions table to highlight major project operations, links to related project information and help pages to familiarize users with the various features of the catalog interface. For users who may be accessing the catalog through limited bandwidth connections such as a cellular network, there will be a low-bandwidth catalog interface to provide quick and easy access to the latest reports and products. The DC3 Field Catalog front page will be customized to provide pertinent project information, real-time severe weather alerts for the Operations Center location and rapid access to the most popular catalog features and will include access to the GIS display tools like Catalog Earth and the Mission Coordinator displays as well as the waypoint calculator and Multi-panel display interface. Access to project chatrooms will be provided through the Field Catalog with a link on the front page as well.

<u>GIS Display tools</u>

The Mission Coordinator and Catalog Earth displays are the main GIS display tools that will be provided by EOL for the DC3 campaign. The Mission Coordinator display is a real-time tool for situational awareness and decision-making aboard the NCAR GV aircraft. This display will contain a small subset of products pertinent to aircraft operations from the Field Catalog that can be displayed along with GV and other aircraft tracks. The Mission Coordinator display is also accessible to forecasters and aircraft coordinators on the ground. The Catalog Earth display is a GIS tool that is integrated into the Field Catalog and provides access to a larger number of real-time products as well as an ability to replay products from any previous day during the campaign. For DC3, a mobile version of the Catalog Earth tool is also being fielded that will provide access to real-time products and instrument locations for those operating mobile facilities on the ground.

<u>IRC Chat</u>

EOL will provide IRC chat services as the primary communications tool between the various regional centers and the mobile and airborne facilities. A number of logged chatrooms will be provided for DC-3 including:

#DC3 – for chat related to mission coordination and real-time decision for all DC3 facilities

#GV – for chat related to instrument issues aboard the GV

#DC3-AL – for chat related to mission coordination and real-time operational decisions with the DC3 Alabama Regional Center

#DC3-CO – for chat related to mission coordination and real-time operational decisions with the DC3 Colorado Regional Center

#DC3-OK – for chat related to mission coordination and real-time operational decisions with the DC3 Oklahoma Regional Center

#DC8 - for chat related to instrument issues aboard the DC-8

After the DC-3 campaign is completed, the logs from these chatrooms will be sanitized to remove sensitive information and will become part of the long-term data archive for the project. As many project participants will be connecting to chat via different networks including satcom and possibly cellular, dropouts may occur when the user loses their internet connection or is in a no-coverage area. In each of the logged chatrooms a replay capability is provided so that when connectivity is re-established the user can query the system to replay all messages in a given chatroom sent during the last user selectable number of minutes. The chat service also provides the capability for users to have private conversations that are not logged should they wish to move their discussion to a separate chatroom or desire to exchange sensitive information. Help documentation is available in the Field Catalog that describes all of these features along with a description of the chat interface and common chat commands.

10.5 Data Archive and Access

The DC3 will take advantage of the capabilities at existing DDACs to implement a distributed data management system. This system will provide "one-stop" single point access (Project Portal) at EOL using the web for search and order of DC3 data from DDACs operated by different agencies/groups with the capability to transfer data sets electronically from the respective DDAC to the user. Access to the data will be provided through a Data Management link from the DC3 Project page (http://www.eol.ucar.edu/dc3/). This Data Management link will contain general information on the data archive and activities on-going in DC3 (i.e. documents, reports), data submission instructions and guidelines, the DC3 DMWG activities, links to related programs and projects, and direct data access via the various DDACs. Parts of the website will be password protected and access restricted, as appropriate.

EOL will be responsible for the long-term data stewardship of DC3 data and metadata. This includes ensuring that "orphan" datasets are properly collected and archived, verifying that data at the various DDACs will be archived and available in the long-term, and that all supporting information (e.g. Field Catalog) are included in the archive.

10.5.1 Data Merges

Data from the airborne platforms will be submitted in ICARTT format to a NASA server. NASA-Langley personnel will provide tools to test that the format follows the ICARTT protocols. They will also generate merges of the submitted data on various timebases to allow direct comparisons of data collected at slightly different times and to provide input to constrained numerical models.

"Composite" datasets will be created that will bring together data from different observing net-works. The data will be converted to a common format and will undergo uniform quality control. Various "Composites" will be made for all three stages of data (field, preliminary, and final).

11. Education and Outreach (WG)

WEB 2.0

• **Outreach Website:** Several DC3 specific pages including: DC3 Home, Platforms & Instruments, 5 Quick Questions, & Outreach Calendar

• **Google Earth:** Develop a Google Earth Layer showing all the facility & platforms locations

• **Blog:** Interested students (undergraduate & graduate students) blogging on a pre-set blog that is linked from the DC3 section of the Field Projects website (I will co-ordinate for them)

• **Facebook/Twitter:** DC3 related posts on the EOL Facebook Page

• **YouTube:** Post DC3 videos on EOL YouTube Channel

• **Video:** At least 1 video describing the science that will be conducted and why it is important to the public

UCAR COLLABORATION

• **COMET:** Collaborate with UCAR's COMET to produce a DC3 related module

• **Communications:** Collaborate with UCAR Communications for a DC3 Press Release

• **SOARS Students**: Inquire with SOARS/Rebecca Hacker-Santos about ways to get SOARS protégé involved

• **HIRO Students**: Inquire with HIRO/Rebecca Hacker-Santos about ways to get HIRO student involved, might be tricky involving high school student

OUTREACH EVENTS

• **Open House:** Coordinate with DC-8 EO coordinator for an open house during the time all 3 aircraft are present. Understanding the need for back-up plans due to weather and research needs, as well as respecting hard-down days

- **GV:** 6 May- 30 June
- **DC-8:** 8 May - 30 June
- **Falcon:** 28 May- 15 June

• **SAFECON (Student aircraft flying competition) (10-19 May 2012):**

• Megan Henderson - SAFECON Student Ambassador, meg4z11@k-state.edu

• Kurt Barhart - Head of Aviation Department @ KSU, Salina, kurtb@sal.ksu.edu

• Thomas Karcz - Assistant Professor KSU; Department of Aviation, tkarcz@Ku.edu

- John Haacke - coordinate SAFECON booth set up through him
- Jim Moore talk at Orientation Meeting - operations, safety & DC3 overview
- 7 May 2012 - Set Up
- 14-19 May 2012 - Competition
- See complete SAFECON schedule below
- Contact Megan Henderson about exhibit
- EOL will have booth present during exhibits time

• **Public Presentations** - coordinate through Melissa McCoy (SAA)**:**

- Salina civic associations monthly gatherings (needs exploring)

- Kansas Wesleyan University
- Rotary Club
- Elks Club
- The Land Institute - http://www.landinstitute.org
- Tim Rogers, SAA = POC, trogers@salair.org, o. 785.827.3914
- Girl & Boy Scouts
- Library
- Churches
- Schools & summer camps

- **Kansas State Aviation School**: Thomas Karcz contact

- **Smoky Hill River Festival (7-10 June 2012):** Have booth at the River Festival with info about DC3 and doing radar & weather activities with the families from the Radar & Weather Together book. http://www.riverfestival.com/salina/

PRINT MATERIALS

- **DC3 Brochure:** In development
- **DC3 Stickers:** In development, waiting on desired URL from web contractor
- **Media**: Contact local papers and other media outlets
- **Airplane Pens:** ~500, TBD
- **Lanyard with USB Flash Drive:** ~250, TBD

PI LED EDUCATION & OUTREACH ACTIVITIES

- **Undergraduate & Graduate Students:** Communicating with PIs about their plans for education and incorporating students into the project

12. Reports, Presentations, and Scientific Papers

12.1 Publication and Presentation Policy

12.2 Reports to Stakeholders

13. Appendices

Appendix A. PIs, Committees, and the Science Team

Principal Investigators

Mary Barth, National Center for Atmospheric Research
William Brune, Pennsylvania State University
Christopher Cantrell, National Center for Atmospheric Research
Steven Rutledge, Colorado State University

DC3 Scientific Steering Committee

Larry Carey, University of Alabama at Huntsville
Owen R. Cooper, NOAA Earth Systems Research Laboratory and CIRES, University of Colorado
James H. Crawford, NASA-Langley
Alan Fried, University of Colorado
Andrew Heymsfield, National Center for Atmospheric Research
Prof. Paul R. Krehbiel, New Mexico Institute of Mining and Technology
Don MacGorman, CIMMS, University of Oklahoma
Laura Pan, National Center for Atmospheric Research
Kenneth E. Pickering, NASA-Goddard
Jeff Stith, National Center for Atmospheric Research
Andrew Weinheimer, National Center for Atmospheric Research

DC3 Science Team

GV

CAMS: Alan Fried (CU), Petter Weibring (NCAR), Dirk Richter (CU), James Walega (NCAR)
TOGA: Eric Apel (NCAR), Rebecca Hornbrook (NCAR), Alan Hills (NCAR), Daniel Riemer (U Miami)
GTCIMS: Greg Huey (Georgia Tech), Bob Stickel (Georgia Tech), David Tanner (Georgia Tech), John Nowak (NOAA), Andy Neuman (NOAA)
P-CIMS: Dan O'Sullivan (USNA), Brian Heikes (URI), Ashley McNeill (URI), Indira Silwal (USNA), Victoria Treadway (URI)
NO_x, O_3, CO, CO_2, CH_4: CARI – Andy Weinheimer (NCAR), Frank Flocke (NCAR), Teresa Campos (NCAR), David Knapp (NCAR), DeeDee Montzka (NCAR), Melodye Rooney (), Geoff Tyndall (NCAR)
HARP: Sam Hall (NCAR), Kirk Ullmann (NCAR)
VCSEL: Mark Zondlo (Princeton), Minghui Diao (Princeton), Josh DiGangi (Princeton), Anthony O'Brien (Princeton)
CLH: Linnea Avallone (CU), Samuel Dorsi (CU), Andrew Kren (CU)
SMPS: Jim Smith (NCAR), Dave Rogers (NCAR), John Ortega (NCAR)
UHSAS: Dave Rogers (NCAR)
Water CN: RAF
CDP: RAF
2D-C: RAF

3V-CPI: RAF

Aircraft Operations: Allen Schanot (NCAR), Ed Ringleman (NCAR), Stephen Thompson (NCAR), Henry Boynton (NCAR), “Scotty” McClain (NCAR), William Cooper (NCAR), John Cowan (NCAR), John Cusack (NCAR), Kip Eagan (NCAR), Bill Irwin (NCAR), Jorgen Jensen (NCAR), Brent Kidd (NCAR), Jason Morris (NCAR), Larry Murphy (NCAR), Bob Olson (NCAR), Mike Reeves (NCAR), Dave Rogers (NCAR), Aaron Steinbach (NCAR), Jeff Stith (NCAR), Hung Ta (NCAR), Kurt Zrubeck (NCAR), Chris Cantrell (NCAR), Mark Lord (NCAR), Pavel Romashkin (NCAR)

DC-8

AMS: Jose Jimenez (CU), Pedro Campuzano-Jost (CU), Doug Day (CU), Patrick Hayes (CU), Amber Ortega (CU), Brett Palm (CU), Donna Sueper (CU)

AOP: Charles Brock (NOAA), Daniel Lack (NOAA, CIRES), Daniel Murphy (NOAA), Justin Langridge (NOAA, CIRES), Daniel Law (NOAA), Matthews Richardson (NOAA), Nick Wagner (NOAA)

APR-2: Simone Tanelli (JPL)

ATHOS: William Brune (PSU), David Miller (PSU), Binh Tran (PSU), Jingqiu Mao (Princeton), Xinrong Ren (NOAA), Li Zhang ()

AVOCET: Andreas Beyersdorf (NASA-Langley), Yonghoon Choi (NASA-Langley), Jimmy Geiger (NASA-Langley), Melissa Yang (NASA-Langley), Krishna Vadrevu (Maryland), Donald Blake (UC-Irvine), Yonghoon Choi (NASA-Langley), James Geiger (NASA-Langley)

BBR: Anthony Bucholtz (NRL), Elizabeth Reid (NRL)

CAFS: Sam Hall (NCAR), Kirk Ullmann (NCAR), Sebastian Schmidt (CU)

CIT-CIMS: Paul Wennberg (CalTech), John Crounse (CalTech), Jason St. Clair (CalTech), Alex Teng (CalTech)

CSD-CL: Tom Ryerson (NOAA), Ilana Pollack (CIRES), Jeff Peischl (CIRES), David Fahey (NOAA)

DACOM and DLH: Glenn Diskin (NASA-Langley), Glen Sachse (NIA), James Podolske (NASA-Ames), Tom Slate (NASA-Langley)

DASH-SP: Armin Sorooshian (Arizona), Lindsay Mauldin (OU), Taylor Shingler (Arizona), Zhen Wang ()

DFGAS: Alan Fried (NCAR), Petter Weibring (NCAR), Dirk Richter (NCAR), James Walega (NCAR), Gary Granger (NCAR)

DIAL-HSRL: Johnathan Hair (NASA-Langley), Carolyn Butler (NASA-Langley), James Collins (NASA-Langley), Marta Fenn (NASA-Langley), Syed Ismail (NASA-Langley), Amin Nehrir (Montana State), Anthony Notari (NASA-Langley)

GT-CIMS: Greg Huey (Georgia Tech), David Tanner (Georgia Tech), Andy Neuman (NOAA), Dexian Chen (Georgia Tech), Jin Liao (Georgia Tech), Jeff Shook (Georgia Tech)

HD-SP2: Ru-shan Gao (NOAA), Joshua Schwarz (NOAA), Anne Perring (NOAA), Laurel Watts (NOAA)

ISAF: Thomas Hanisco (NASA-Goddard), Maria Cazorla (NASA-Goddard), Randy Kawa (NASA-Goddard), Andrew Swanson ()

LARGE: Bruce Anderson (NASA-Langely), Andreas Beyersdorf (NASA-Langley), Gao Chen (NASA-Langley), Lee Thornhill (NASA-Langley), Luke Ziemba (NASA-

Langley), Antony Clarke (Hawaii), Athanasios Nenes (Georgia Tech), Suzanne Crumeyrolle (NASA-Langley), Richard Moore (NASA-Langley), Edward Winstead (NASA-Langley)

MMS: Paul Bui (NASA-Ames), Cecilia Chang (NASA-Ames)

PALMS: Karl Froyd (NOAA), Daniel Murphy (NOAA)

PI-Neph: Vanderlei Martins (UMBC), Steven Buczkowski (UMBC), Dominik Cieslak (UMBC), Gergely Dolgos (UMBC), Reed Espinosa (UMBC), Lorraine Remer (NASA-Goddard)

PTR-MS: Armin Wisthaler (Innsbruck), Tomas Mikoviny (Innsbruck)

SAGA: Jack Dibb (UNH), Eric Scheuer (UNH)

SPEC: Paul Lawson (SPEC), Sara Lance (SPEC), Christoph Roden (SPEC), Mike Carrithers (SPEC), Ted Fisher (SPEC), Randy Horn (SPEC), Nick Krause (SPEC), Quix Mo (SPEC), Don Stone (SPEC), Sarah Woods (SPEC)

SSFR: Sebastian Schmidt (CU), Peter Pilewskie (CU), Warren Gore (NASA-Ames), Sam Hall (NCAR), Bruce Kindel (CU), Shi Song (CU), Antonio Trias (NASA-Ames)

TD-LIF: Ron Cohen (UC-Berkeley), Charity Garland (UC-Berkeley), Benjamin Nault (UC-Berkeley), Sally Pusede (UC-Berkeley), Paul Wooldrdge (UC-Berkeley)

WAS: Donald Blake (UC-Irvine), Nicola Black (UCI), Barbara Barletta (UCI), Gregory Hartt (UCI), Yu-Hsin Hung (UCI), Jason Schroeder (UCI), Isobel Simpson (UCI)

Aircraft Operations: Frank Cutler (NASA-Dryden), Rick Shetter (NSERC), Eric Buzay (NSERC), James Crawford (NASA-Langley), William Brune (PSU), David Van Gilst (NSERC), Adam Webster (NSERC)

Falcon

Heidi Huntrieser (DLR), Andreas Minikin (DLR), Andrea Hausold (DLR), Hans Schlager (DLR), Heinfried Aufmhoff (DLR), Daniel Futterer (DLR), Christoph Grad (DLR), Katharina Heimerl (DLR), Jin Kim (DLR), Michael Lichtenstern (DLR), Anja Reiter (DLR), Yu Ren (DLR), Anke Roiger (DLR), Monika Scheibe (DLR), Philipp Weber (DLR), Bernadett Weinzierl (DLR), Roland Welser (DLR), Alexander Wolf (DLR), Helmut Ziereis (DLR), Martin Zoeger (DLR)

Colorado Ground-Based

Steve Rutledge (CSU), Pat Kennedy (CSU), Bill Brown (NCAR), Tim Lang (CSU)

Oklahoma & Texas Ground-Based

Don MacGorman (NOAA), Mike Biggerstaff (OU), Eric Bruning (TTU), Daniel Betten (OU), William Rison (NMT), Sean Waugh (NOAA), Efren Afante (OU), Austin Alford (OU), Blake Allen (OU), Jeffrey Biggerstaff (OU), Michael Bowlan (OU), Gordon Carrie (OU), Doug Crauder (OU), Kyle Pennington (OU), Curtis Riganti (OU), Elizabeth Rockwell (OU), Chris Schwarz (OU), Corey Simma (OU), Kyle Thiem (OU)

Alabama Ground-Based

Larry Carey (UAH), Elise Schultz (UAH), Dustin Phillips (UAH)

Forecasting, Modeling, and Data Archive

Morris Weisman (NCAR), Mary Barth (NCAR), Louisa Emmons (NCAR), Gao Chen (NASA-Langley), Andreas Dörnbrack (DLR), Dale Allen (UMd), Chris Hanlon

(PSU), Patrick Hyland (OU), Mijeong Park (NCAR), Ryan Rogers (UAH), Russ Schumacher (CSU), Arthur Small (VentiRisk), Hans Verlinde (PSU), Kristin Cummings (UMd), Theodore Lyons (UMd), Ken Pickering (UMd), Owen Cooper (NOAA), Lamont Bain (UAH), Mary Barth (NCAR), Jerome Brioude (NOAA)

Logistics, Operations Support, Website, Communications, Data, E&O

Vidal Salazar (NCAR), Jim Moore (NCAR), Greg Stossmeister (NCAR), Steve Williams (NCAR), Mike Daniels (NCAR), Brigitte Baeuerle (NCAR), Alison Rockwell (NCAR), Gao Chen (NASA-Langley), Dennis Flanigan (NCAR), Erik Johnson (NCAR), William Haddon (NCAR), Gretchen Mullendore (UND), Chris Webster (NCAR), Tom Balzer (NCAR), Laura Pan (NCAR), Carl Drews (NCAR), Jose Meitin (NCAR), Rochell Sherman (NCAR), Brandon Slaten (NCAR), Briesa St. Martin (NCAR), Jody Williams (NCAR), Ted Russ (NCAR), Mike Paxton (NCAR)

Appendix B. Contact Information

Principal Investigators

	Email address	Work Telephone	Home/Cell Telephone	Salina Hotel
Mary Barth	barthm@ucar.edu	303-497-8186		
Bill Brune	brune@meteo.psu.edu			
Chris Cantrell	cantrell@ucar.edu	303-497-1479	303-947-7466	Candlewood
Steve Rutledge	rutledge@atmos.colostate.edu			

Campaign Hotels

Candlewood Suites

2650 Planet Ave., Salina, KS
785-823-6939
Block code: DC3 Group
http://www.candlewoodsuites.com

Country Inn & Suites

2760 S 9th St., Salina, KS
785-827-1271
Block code: DC3-NCAR
http://www.countryinns.com/salina-hotel-ks-67401/kssalina

Fairfield Inn & Suites

1740 W Crawford St., Salina, KS
785-823-6900, kara.cox@ihrco.com
Block name: DC3
http://www.marriott.com/hotels/travel/slnfi-fairfield-inn-salina/

Hampton Inn Salina

401 W Schilling Rd., Salina, KS
785-823-9800
Block code: DC3
http://hamptoninn.hilton.com/en/hp/hotels/index.jhtml?ctyhocn=SLNKSHX

Ramada Conference Center

1616 W Crawford St., Salina, KS
785-823-1739
Block code: DC3
http://www.ramada.com/hotels/kansas/salina/ramadaconference-center-salina/hotel-overview

Table B-2. Some of the 31 Hotels in Salina, KS, including the designated campaign hotels and others.

Name ↑	Address	Phone	Website
Americas Best Value Inn	2403 S 9th St, Salina, KS	(785) 827-5511	www.americasbestvalueinn.com
Baymont Inn & Suites	745 Schilling Rd, Salina, KS	(877) 229-6668	
Best Western Heart Of America Inn	632 Westport Blvd, Salina, KS	(785) 827-9315	www.bestwestern.com
Best Western Mid-America Inn	1846 N 9TH St, Salina, KS	(785) 827-0356	
Candlewood Suites	2650 Planet Ave, Salina, KS	(888) 226-3639	
Comfort Inn	1820 W Crawford St, Salina, KS	(785) 826-1711	www.choice.com
Country Inn & Suites	2760 S 9th St, Salina, KS	(785) 827-1271	www.countryinns.com
Courtyard By Marriott Salina	3020 Riffel Dr, Salina, KS	(800) 919-4795	marriott.com
Days Inn	407 W Diamond Dr, Salina, KS	(785) 823-9791	www.daysinn.com
Fairfield Inn Salina	1740 W Crawford, Salina, KS	(785) 823-6900	www.choicehotels.com
Hampton Inn	401 W Schilling Rd, Salina, KS	(785) 823-9800	
Holiday Inn Express Hotel & Suites	201 East Diamond Dr, Salina, KS	(785) 827-9000	
Holiday Inn Of Salina	1616 W Crawford, Salina, KS	(785) 823-1739	
Howard Johnson Motel	2403 S 9TH, Salina, KS	(785) 827-5511	
Motel 6	635 W Diamond Dr, Salina, KS	(785) 827-8397	
Quality Inn & Suites	2110 W Crawford Ave, Salina, KS	(785) 825-2111	www.choicehotels.com
Rodeway Inn	1640 W Crawford, Salina, KS	(785) 823-9215	
Salina Inn	222 E Diamond Dr, Salina, KS	(785) 825-1571	
Sleep Inn & Suites	3932 S 9th, Salina, KS	(785) 404-6777	www.sleepinn.com
Super 8 Motel	1640 W Crawford St, Salina, KS	(785) 823-9215	
Travelodge Salina	1949 North 9th St, Salina, KS	(785) 825-8211	www.travelodge.com

More Hotels

Salina hotels

Restaurants

http://www.salinafyi.com/marketplace/categories/food-and-dining/

Salina Information

http://www.salina.com

Salina Airport

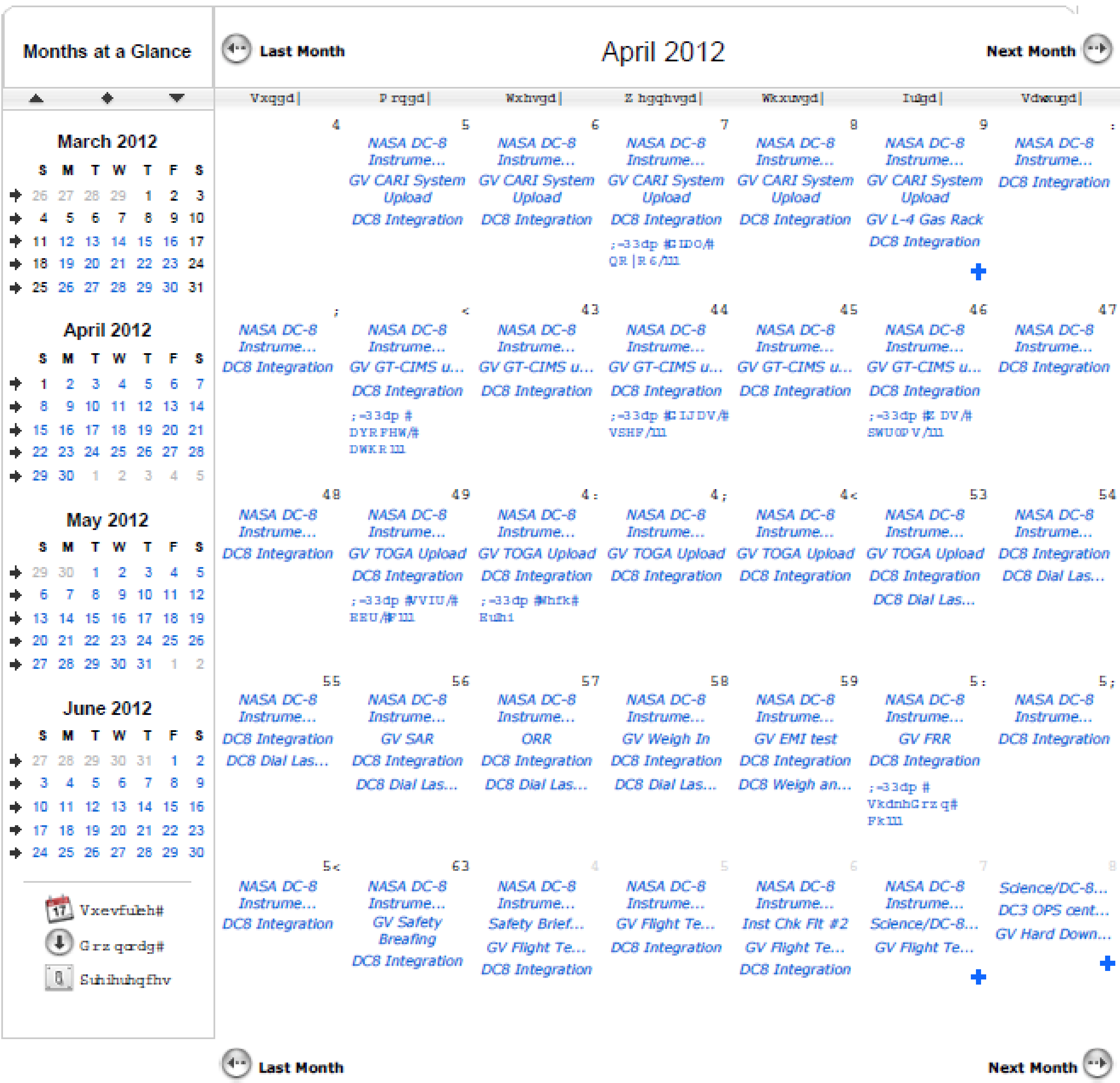
http://www.salinaairport.com

Salina Airport FBOs

America Jet	785-825-6261	800-748-8260
Flower Aviation	785-825-6739	

Appendix C1. DC3 Intensive Observational Period Calendar

See latest version at:
http://www.eol.ucar.edu/projects/dc3/calendar/dc3_general_cal.html



Months at a Glance

Last Month | April 2012 | Next Month

Vxqgd|	P rqgd|	Wxhvgd|	Z hgqhvgd|	Wkxuvgd|	Iulgd|	Vdwxugd|
4	5 NASA DC-8 Instrume... GV CARI System Upload DC8 Integration	6 NASA DC-8 Instrume... GV CARI System Upload DC8 Integration	7 NASA DC-8 Instrume... GV CARI System Upload DC8 Integration ;-33dp #GIDO/# QR|R6/III	8 NASA DC-8 Instrume... GV CARI System Upload DC8 Integration	9 NASA DC-8 Instrume... GV CARI System Upload GV L-4 Gas Rack DC8 Integration	: NASA DC-8 Instrume... DC8 Integration
; NASA DC-8 Instrume... DC8 Integration	< NASA DC-8 Instrume... GV GT-CIMS u... DC8 Integration ;-33dp # DYRFHW/# DWKRIII	43 NASA DC-8 Instrume... GV GT-CIMS u... DC8 Integration	44 NASA DC-8 Instrume... GV GT-CIMS u... DC8 Integration ;-33dp #GIJDV/# VSHF/III	45 NASA DC-8 Instrume... GV GT-CIMS u... DC8 Integration	46 NASA DC-8 Instrume... GV GT-CIMS u... DC8 Integration ;-33dp # DV/# SWUOPV/III	47 NASA DC-8 Instrume... DC8 Integration
48 NASA DC-8 Instrume... DC8 Integration	49 NASA DC-8 Instrume... GV TOGA Upload DC8 Integration ;-33dp #VVIU/# EEU/#FIII	4: NASA DC-8 Instrume... GV TOGA Upload DC8 Integration ;-33dp #Whfk# Eulhi	4; NASA DC-8 Instrume... GV TOGA Upload DC8 Integration	4< NASA DC-8 Instrume... GV TOGA Upload DC8 Integration	53 NASA DC-8 Instrume... GV TOGA Upload DC8 Integration DC8 Dial Las...	54 NASA DC-8 Instrume... DC8 Integration DC8 Dial Las...
55 NASA DC-8 Instrume... DC8 Integration DC8 Dial Las...	56 NASA DC-8 Instrume... GV SAR DC8 Integration DC8 Dial Las...	57 NASA DC-8 Instrume... ORR DC8 Integration DC8 Dial Las...	58 NASA DC-8 Instrume... GV Weigh In DC8 Integration DC8 Dial Las...	59 NASA DC-8 Instrume... GV EMI test DC8 Integration DC8 Weigh an...	5: NASA DC-8 Instrume... GV FRR DC8 Integration ;-33dp # VkdnhGrzq# FkIII	5; NASA DC-8 Instrume... DC8 Integration
5< NASA DC-8 Instrume... DC8 Integration	63 NASA DC-8 Instrume... GV Safety Breafing DC8 Integration	4 NASA DC-8 Instrume... Safety Brief... GV Flight Te... DC8 Integration	5 NASA DC-8 Instrume... GV Flight Te... DC8 Integration	6 NASA DC-8 Instrume... Inst Chk Flt #2 GV Flight Te... DC8 Integration	7 NASA DC-8 Instrume... Science/DC-8... GV Flight Te...	8 Science/DC-8... DC3 OPS cent... GV Hard Down...

March 2012

S	M	T	W	T	F	S
26	27	28	29	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

April 2012

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	1	2	3	4	5

May 2012

S	M	T	W	T	F	S
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2

June 2012

S	M	T	W	T	F	S
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Vxevfuleh#
Grzqordg#
Suhihuhqfhv

Last Month | Next Month

Months at a Glance

Last Month | **May 2012** | Next Month

Vxqgd	P rqgd	Wxhvgd	Z hgqhvgd	Wkxuvgd	Iulgd	Vdwxugd
5<	63	4	5	6	7	8
NASA DC-8 Instrument Upload DC8 Integration	NASA DC-8 Instrument Upload GV Safety Breafing DC8 Integration	NASA DC-8 Instrument Upload Safety Brief... GV Flight Te... DC8 Integration	NASA DC-8 Instrument Upload GV Flight Te... DC8 Integration	NASA DC-8 Instrument Upload Inst Chk Flt #2 GV Flight Te... DC8 Integration	NASA DC-8 Instrument Upload Science/DC-8... GV Flight Te...	Science/DC-8... DC3 OPS cent... GV Hard Down...
9	:	;	<	43	44	45
Science/DC-8... GV Ferry To Salina NCAR Science GearT...	DC3 Project Setup GV RAF Ground Ship... <=33dp #Vflhqfh# whdp #p hp ehlll	DC-8 Transit to Sa... Science/DC-8 Truck... GV Flight Testing	GV Flight Testing DC8 Arrival Orientation ...	GV Flight Testing DC8 1st practice flight	GV Flight Testing	GV Flight Testing DC8 2nd Practice Flight
46	47	48	49	4:	4;	4<
GV Flight Testing DC8 1st science flight	GV Flight Testing	DC3 Research Operations	DC3 Research Operations	DC3 Research Operations	ESPO Equip shipped ARC t... DC3 Research Operations	DC3 Research Operations
53	54	55	56	57	58	59
DC3 Research Operations	DC3 Research Operations	DC3 Research Operations	DC3 Research Operations	DC3 Research Operations	All Equip to be at DAOF ... DC3 Research Operations	DC3 Research Operations
5:	5;	5<	63	64	4	5
DC3 Research Operations	DC3 Research Operations	DC3 Research Operations	DC3 Research Operations	DC3 Research Operations	SEAC4RS surface shipment... DC3 Research Operations	DC3 Research Operations

Last Month | Next Month

April 2012

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	1	2	3	4	5

May 2012

S	M	T	W	T	F	S
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2

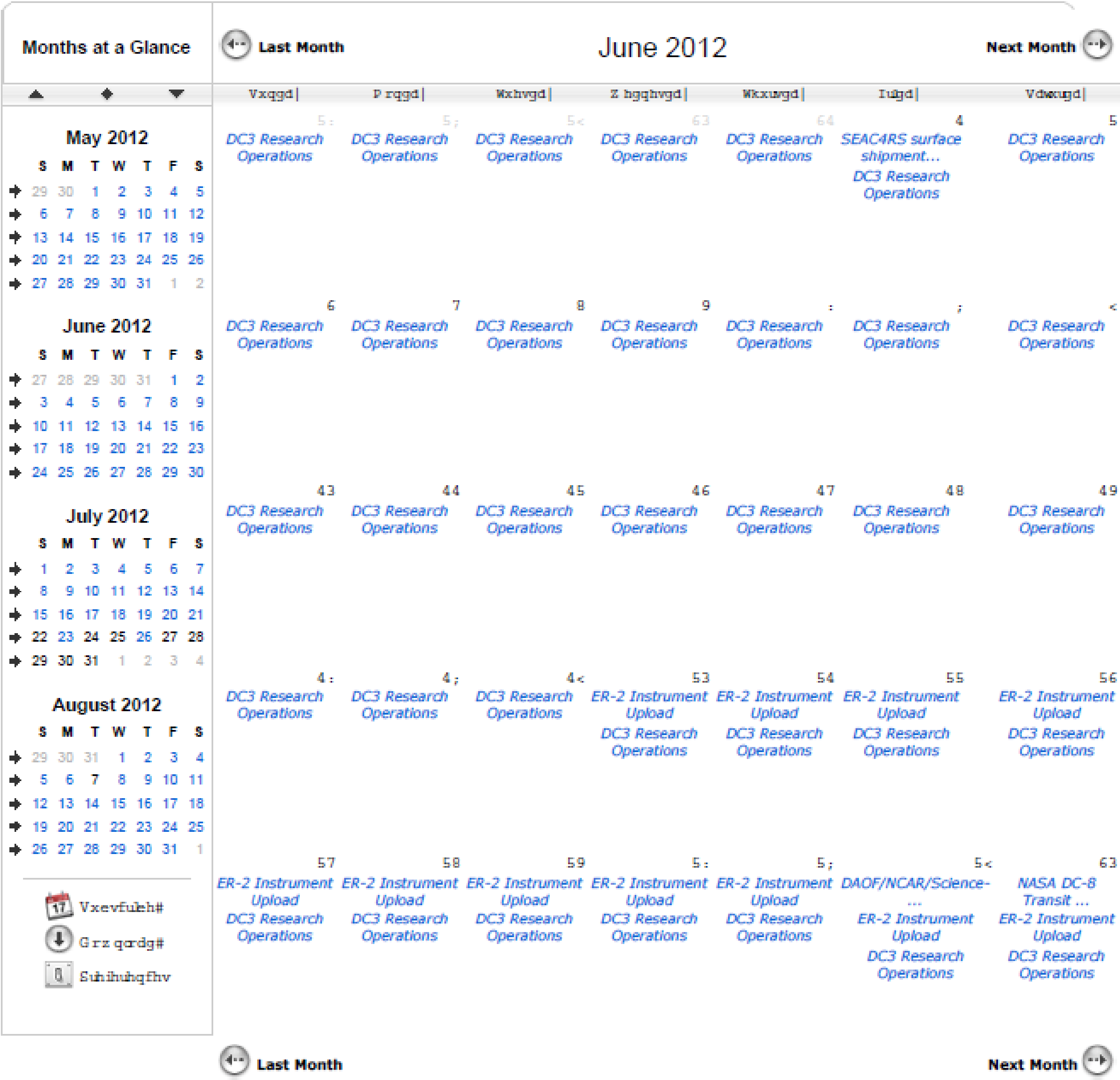
June 2012

S	M	T	W	T	F	S
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

July 2012

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

Vxevfuleh#
Grz qordg#
Suhihuhqfhv



Months at a Glance

May 2012

S	M	T	W	T	F	S
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2

June 2012

S	M	T	W	T	F	S
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

July 2012

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

August 2012

S	M	T	W	T	F	S
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	1

Vxevfuleh#

Grzqordg#

Suhihuhqfhv

Last Month

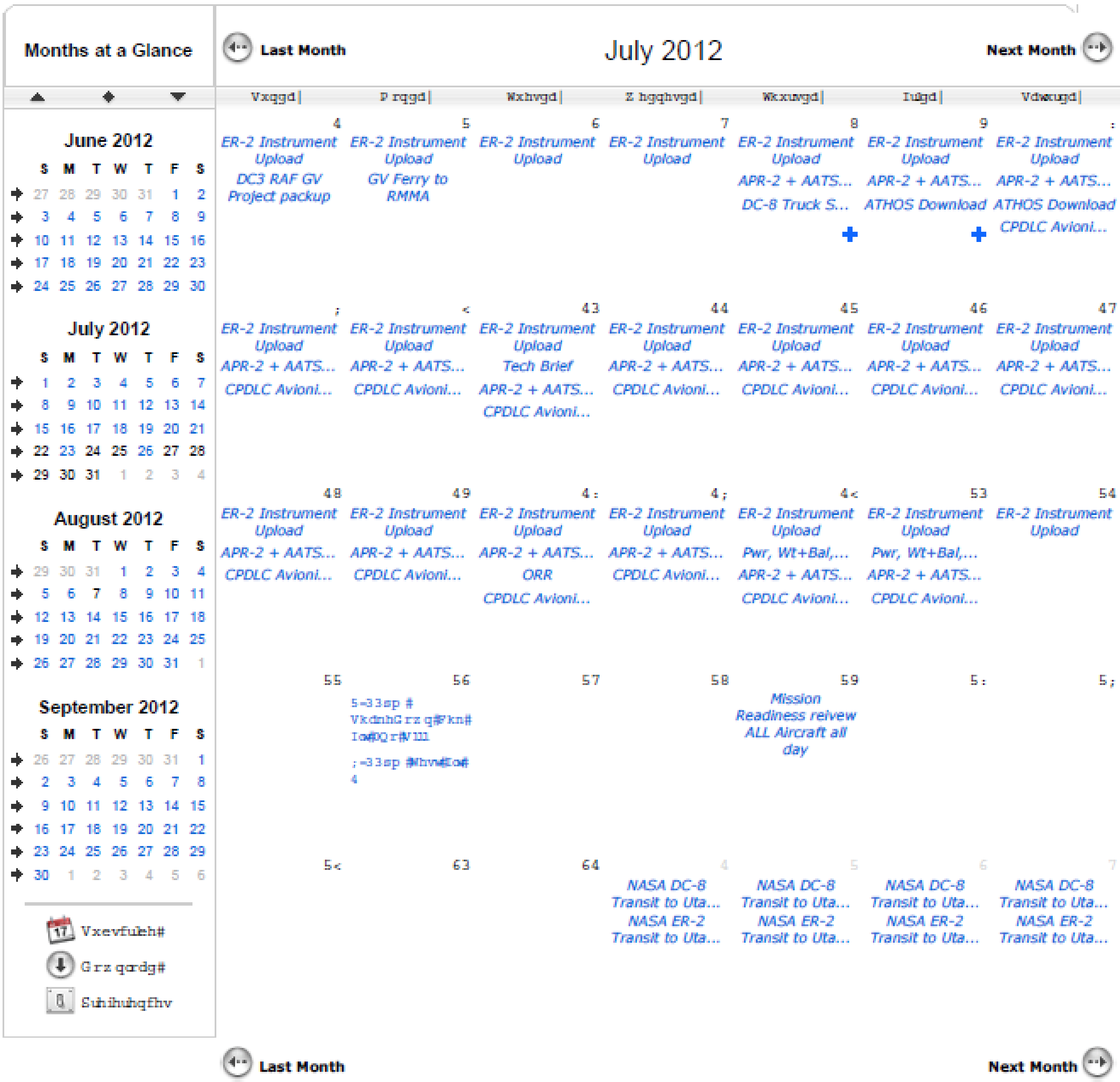
June 2012

Next Month

Vxqgd|	P rqgd|	Wxhvgd|	Z hgqhvgd|	Wkxuvgd|	Iulgd|	Vdwxugd|
5: DC3 Research Operations	5; DC3 Research Operations	5< DC3 Research Operations	63 DC3 Research Operations	64 DC3 Research Operations	4 SEAC4RS surface shipment... DC3 Research Operations	5 DC3 Research Operations
6 DC3 Research Operations	7 DC3 Research Operations	8 DC3 Research Operations	9 DC3 Research Operations	: DC3 Research Operations	; DC3 Research Operations	< DC3 Research Operations
43 DC3 Research Operations	44 DC3 Research Operations	45 DC3 Research Operations	46 DC3 Research Operations	47 DC3 Research Operations	48 DC3 Research Operations	49 DC3 Research Operations
4: DC3 Research Operations	4; DC3 Research Operations	4< DC3 Research Operations	53 ER-2 Instrument Upload DC3 Research Operations	54 ER-2 Instrument Upload DC3 Research Operations	55 ER-2 Instrument Upload DC3 Research Operations	56 ER-2 Instrument Upload DC3 Research Operations
57 ER-2 Instrument Upload DC3 Research Operations	58 ER-2 Instrument Upload DC3 Research Operations	59 ER-2 Instrument Upload DC3 Research Operations	5: ER-2 Instrument Upload DC3 Research Operations	5; ER-2 Instrument Upload DC3 Research Operations	5< DAOF/NCAR/Science-... ER-2 Instrument Upload DC3 Research Operations	63 NASA DC-8 Transit ... ER-2 Instrument Upload DC3 Research Operations

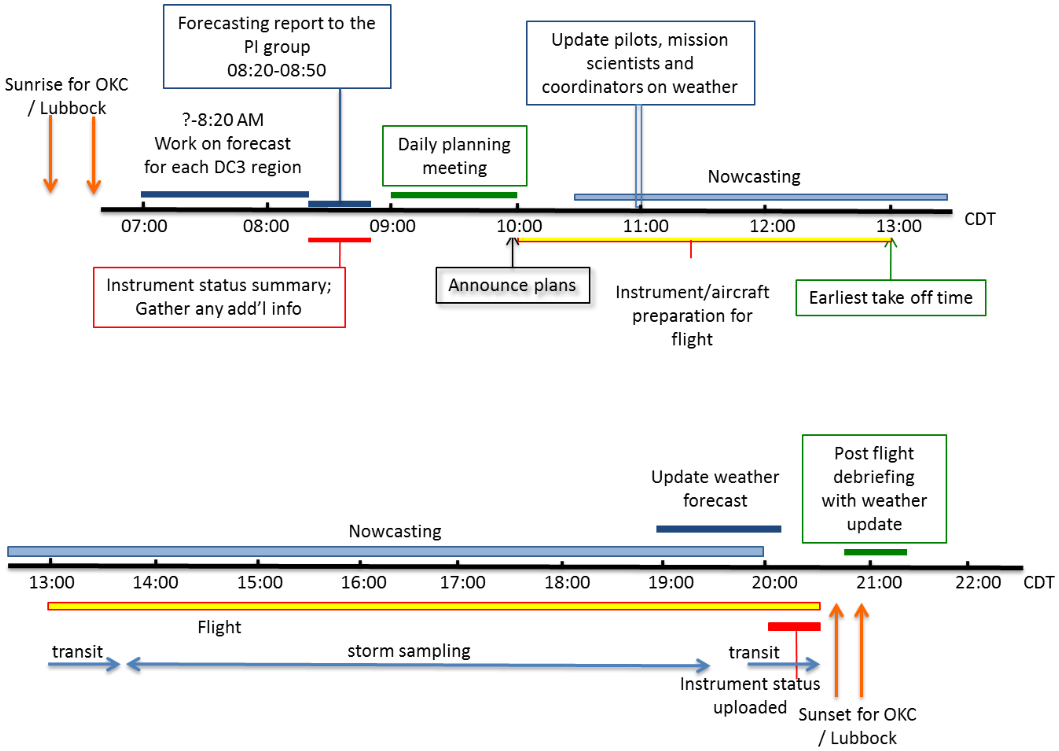
Last Month

Next Month

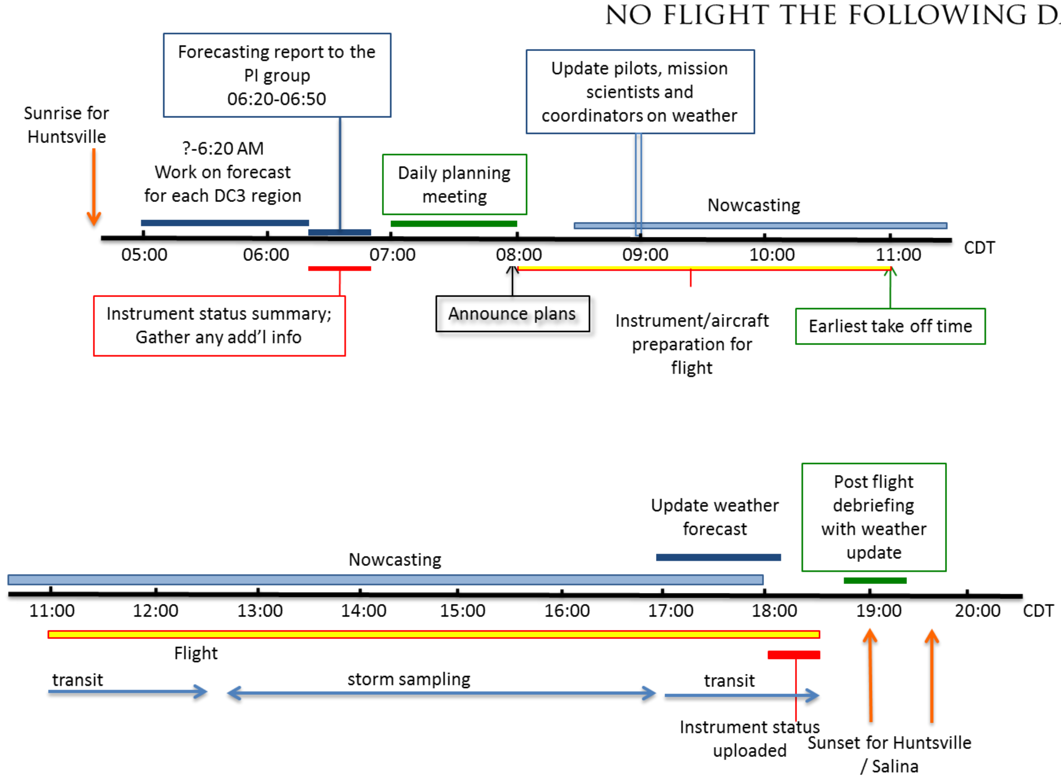

Months at a Glance
Last Month
July 2012
Next Month
June 2012
July 2012
August 2012
September 2012
ER-2 Instrument Upload
DC3 RAF GV Project packup
GV Ferry to RMMA
APR-2 + AATS...
DC-8 Truck S...
ATHOS Download
CPDLC Avioni...
Tech Brief
ORR
Pwr, Wt+Bal,...
Mission Readiness reivew ALL Aircraft all day
NASA DC-8 Transit to Uta...
NASA ER-2 Transit to Uta...
Last Month
Next Month

Appendix C2. Daily Schedule Diagrams

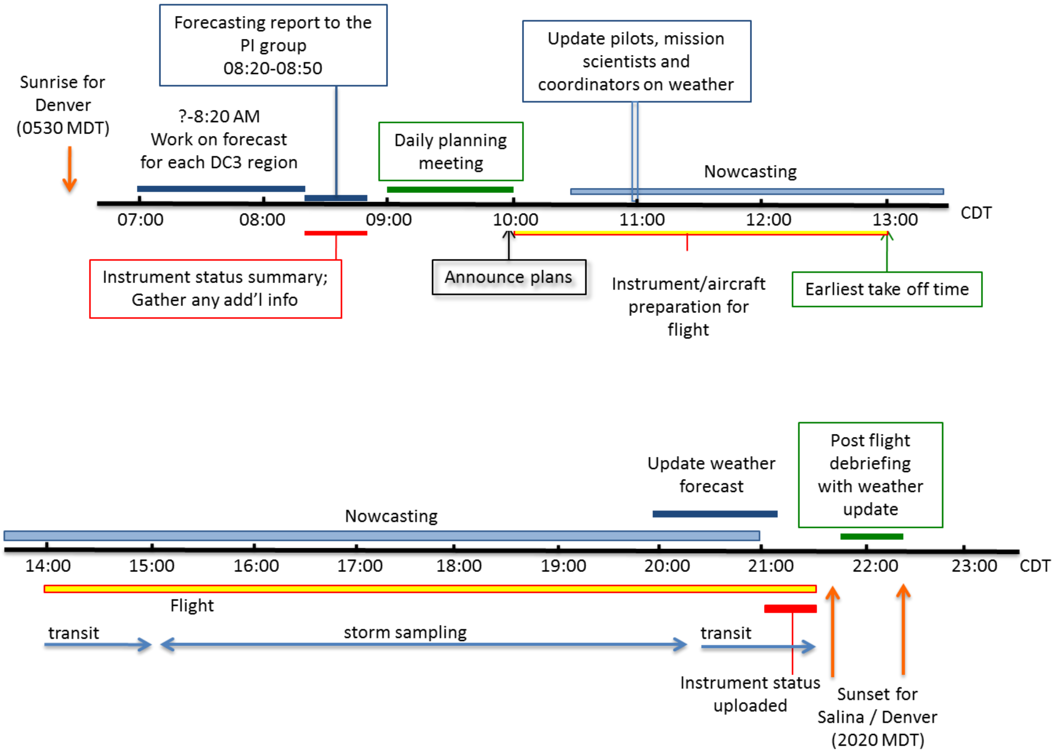
DC3 Daily schedule for active storm in Oklahoma flight day
no flight the following day



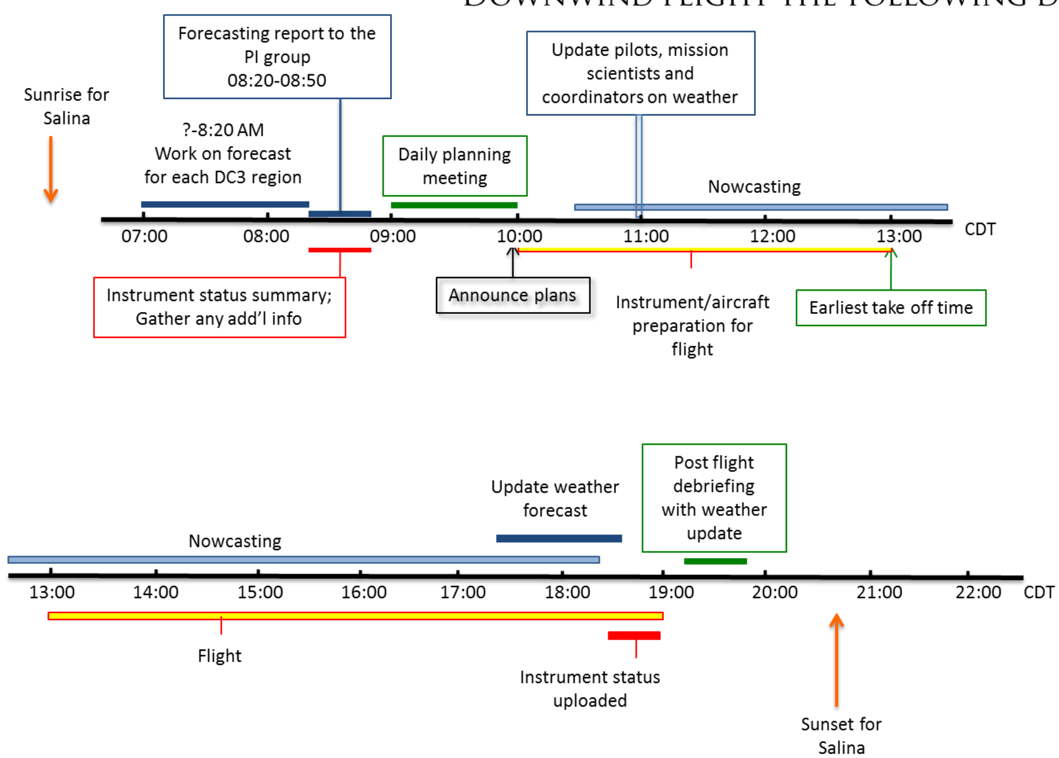
DC3 Daily schedule for active storm in Alabama flight day
no flight the following day



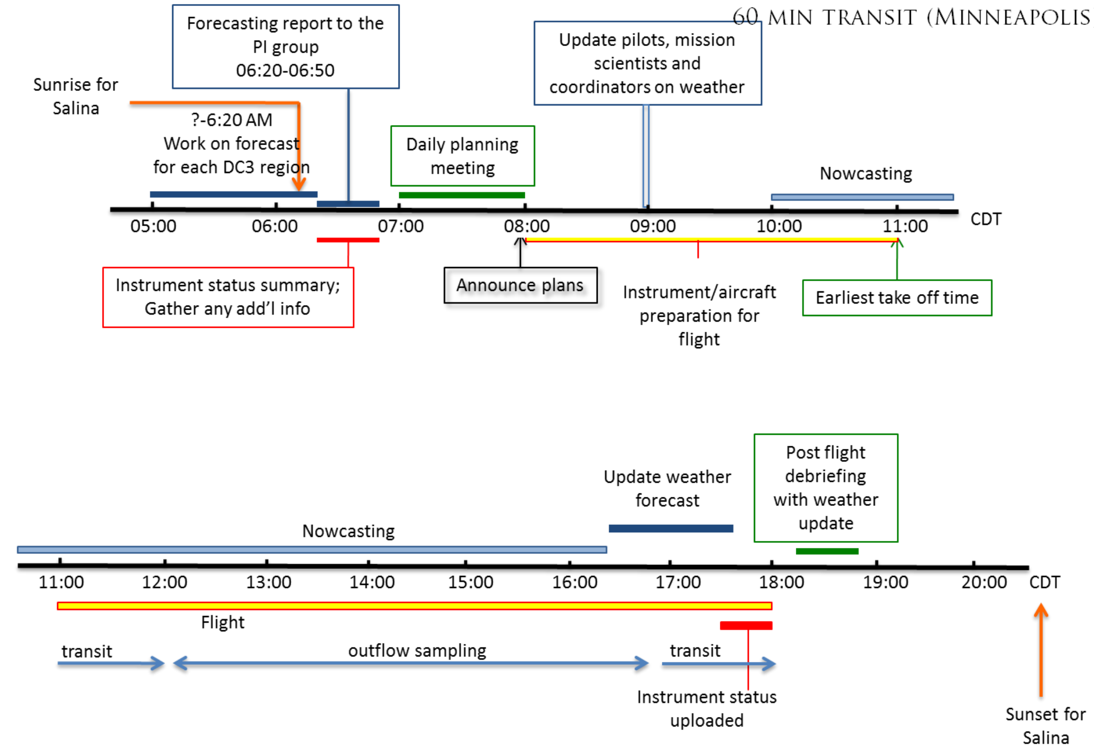
DC3 Daily schedule for active storm in Colorado flight day
No flight the following day



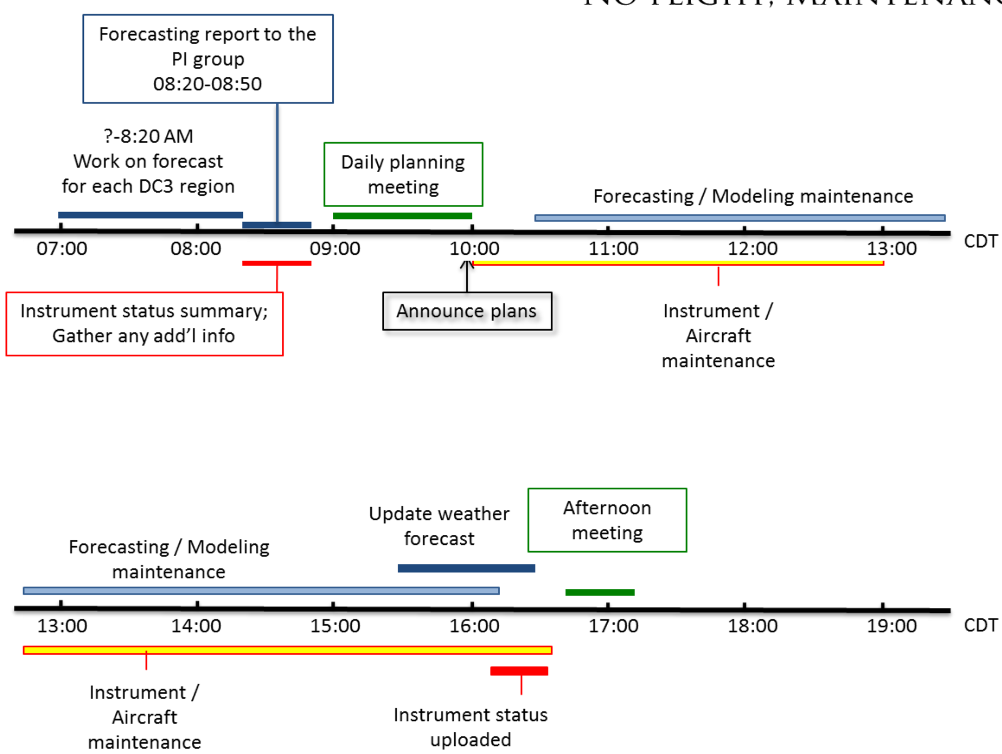
DC3 Daily schedule for active storm flight day
Downwind flight the following day



DC3 Daily schedule for active storm flight day
Downwind flight
60 min transit (Minneapolis)



DC3 Daily schedule for active storm flight day
No flight; Maintenance day



Appendix D. Aircraft Payloads and Cabin Layouts

Table D-1. Payload for the NSF/NCAR GV during DC3.

Instrument	PI	Species /Parameter	Method
O_3	CARI*	O_3	CL
NO_x	CARI	NO, NO_2	CL
CO	CARI	CO	VUV fluorescence
PICARRO	CARI	CO_2, CH_4	CRDS
TOGA	Apel	VOCs, OVOCs, halocarbons	GC/MS
GTCIMS	Huey	HNO_3, HNO_4, SO_2, HCl	CIMS
P-CIMS	Heikes/O'Sullivan	H_2O_2, CH_3OOH	CIMS
CAMS	Fried	HCHO	IR laser spectroscopy
HARP	Hall	Actinic flux, spectral irradiance	Collection, dispersion spectroscopy
VCSEL	Zondlo	H_2O vapor	Laser spectroscopy
CLH	Avallone	H_2O total	TDL spectroscopy
SMPS	Smith/Rogers	Aerosol size distribution	Particle mobility
WCN	RAF	Aerosol number	Optical particle counting
UHSAS	RAF	Aerosol size dist 0.1-1 μm	Laser optical scattering
CDP	RAF	Cloud particle size dist 2-50 μm	Laser optical scattering
2D-C	RAF	Cloud particle imager 25-1600 μm	Diode array images
3V-CPI	RAF	Cloud particle imager 10-1280 μm	Orthog. scattrg plus diode array images
Various	RAF	Lat, long, P, T, DP, speeds, winds	various
DV	RAF	Video images – forward view	Digital camera
ADS	RAF	Data collection system	
Crew: Mission Scientist, Mission Coordinator, 3 Instrument scientists, ADS Technician, Pilot, Co-Pilot			

* The CARI team is Flocke, Weinheimer, Knapp, Montzka, and Campos.

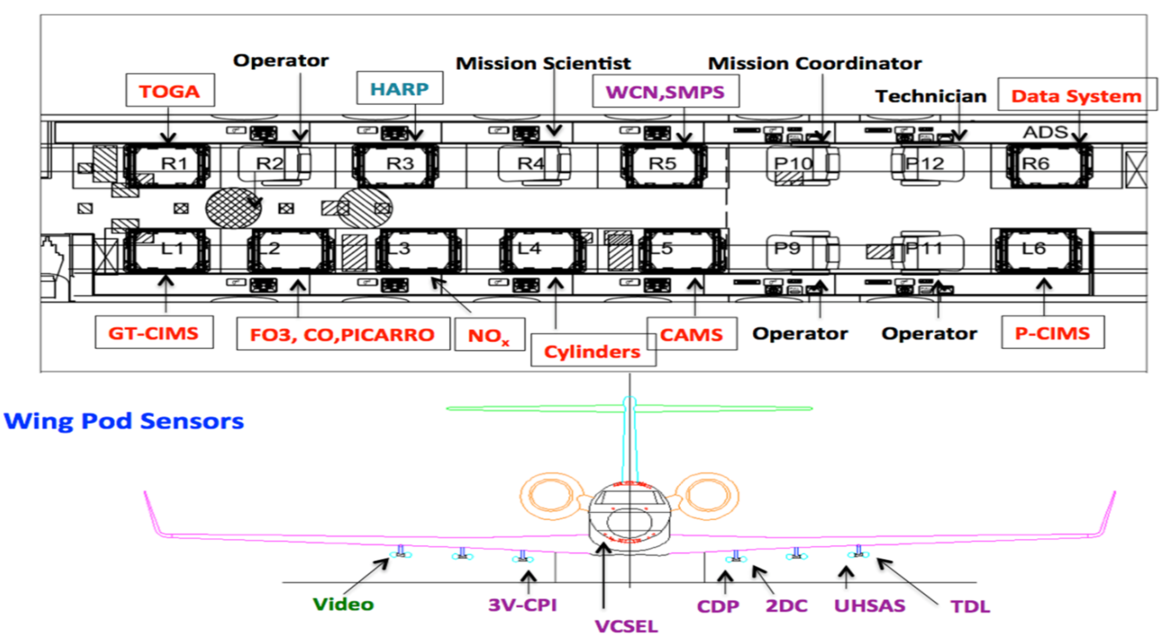


Figure D-1. Payload layout for the NSF/NCAR GV aircraft during DC3.

Table D-2. Payload for NASA DC-8 during DC3.

Instrument	PI	Species/Parameter	Method
CSD CL	Ryerson	NO, NO2, NOy, O3	CL
DLH	Diskin	H2O vapor	TDL spectroscopy
DACOM	Diskin	CO, CH4, N2O	TDL spectroscopy
SAGA	Dibb	HNO3, bulk aerosols	MC/IC, filters
ATHOS	Brune	OH, HO2	LIF
AVOCET	Beyeresdorf	CO2	Differential NDIR
DFGAS	Fried	CH2O	IR laser spectroscopy
SPEC	Lawson	Aerosol parameters	Various
WAS	Blake	VOCs, OVOCs, halo-VOCs	Canister, GC
PTR-MS	Wisthaler	VOCs, OVOCs	PTR-MS
BBR	Bucholtz	Broadband solar & IR	Radiometers
SSFR	Schmidt	Solar & near IR irradiance	
CAFS	Hall	Actinic flux	
PALMS	Murphy	Single particle composition	TOF-MS
AOP	Brock	Aerosol extinct & absorp.	
LARGE	Anderson		
HD-SP2	Gao	Black carbon aerosol	
AMS	Jimenez	Aerosol mass spectra	TOF-MS
TD-LIF	Cohen	NO, NO2, alkyl nitrates	TD-LIF
CIT-CIMS	Wennberg	Peroxides, HNO3, HCN, organic acids	CIMS
GT-CIMS	Huey	PAN, SO2	CIMS
DIAL HSRL	Hair	O3 & aerosol profiles	LIDAR
MMS	Bui	micrometeorology	
ISAF	Hanisco	CH2O	LIF
DASH-SP	Sorooshian		
PI-Neph	Martins		

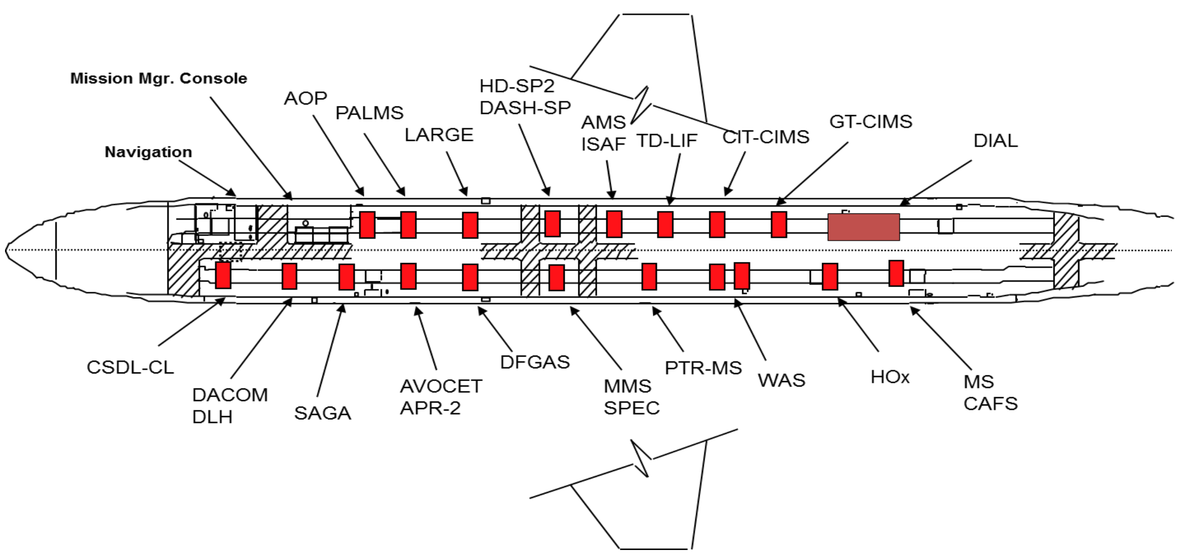


Figure D-2. Cabin layout of the NASA DC-8 aircraft during DC3.

Table D-3. Payload for DLR Falcon during DC3.

Item	Instrument
State Parameters	
Wind direction, speed, temperature, pressure	various
Trace Gases	
O_3	UV absorbance
NO, NO_y	Chemiluminescence
PAN, HNO_3, SO_2	CIMS
CO	VUV fluorescence
CO_2, CH_4	PICARRO
VOCs, halocarbons	Canisters
J(NO_2)	Filter radiometers
PFC Tracer	Adsorption tubes
Aerosol Properties	
Particle number, >5 nm	3 x CPC
Particle number, >10 nm, non-volatile	3 x CPC
Particle size distribution, 70-1000 nm	UHSAS
Particle size distribution, 140-1000 nm	PCASP-100X
Size distribution, 0.4-20 µm	FSSP-300
Size distribution, 0.25-2 µm, total & non-volatile	2 x Grimm OPC 1.29
Absorption coefficient	3-lambda-PSAP
Black carbon concentration	SP2

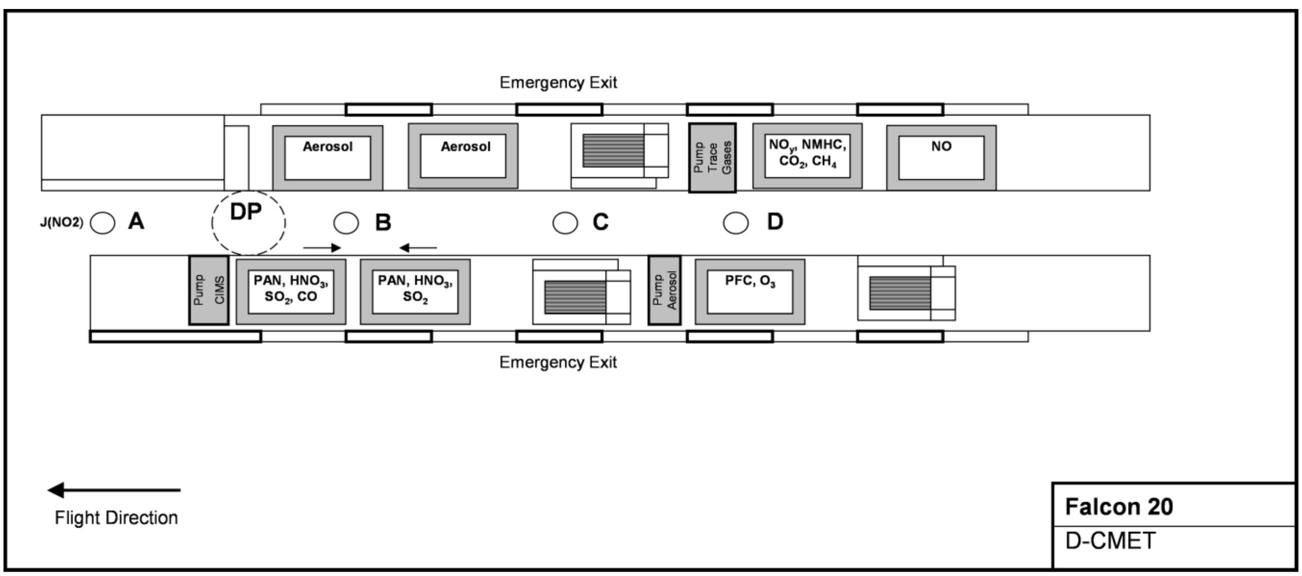
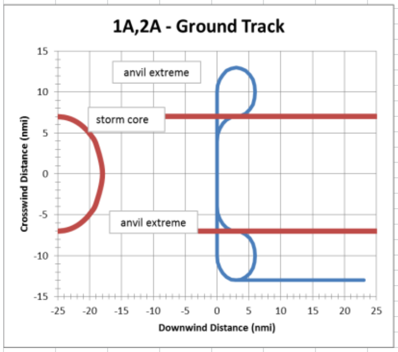
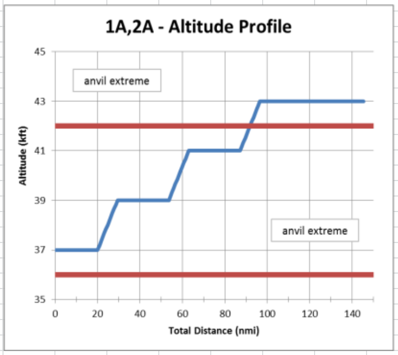


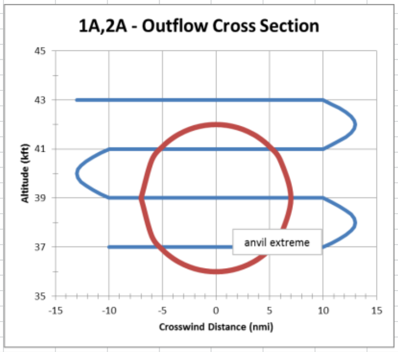
Figure D-3. Cabin layout for DLR Falcon.

Appendix E. Flight Pattern Segment Diagrams

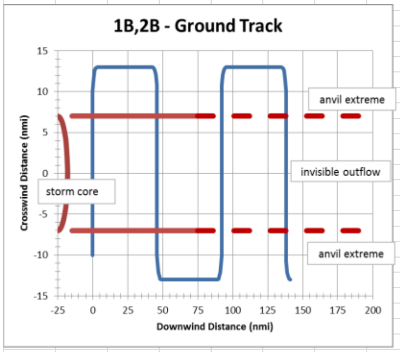
cross anvil, cross fresh outflow, and cross aged outflow

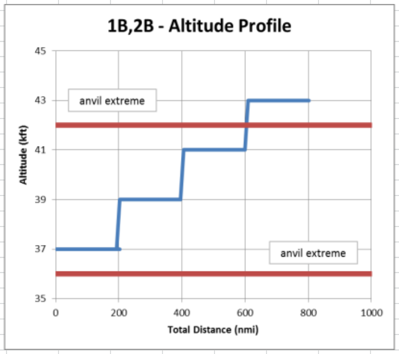


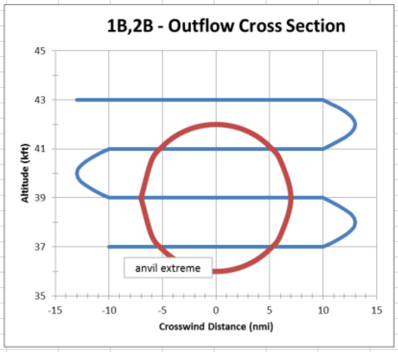




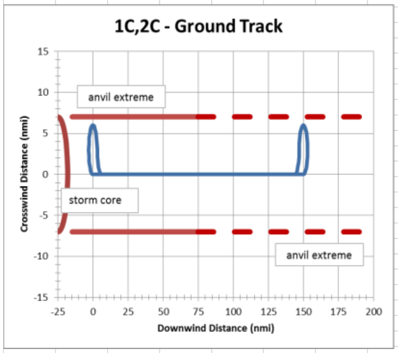
cross anvil, cross fresh outflow, and cross aged outflow, constant altitude

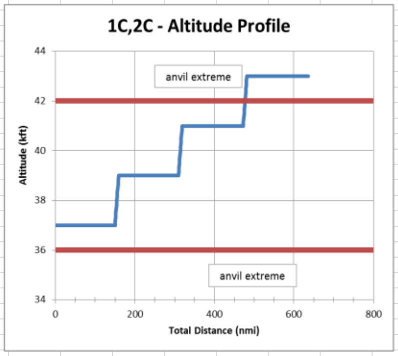


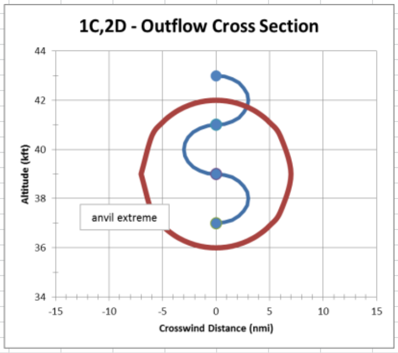




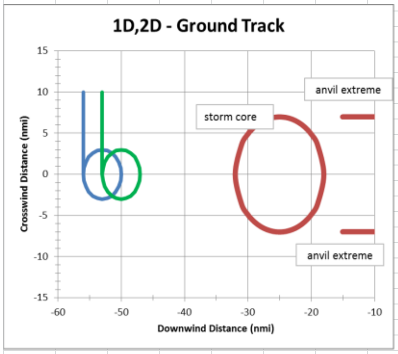
axial anvil, axial fresh outflow, axial aged outflow

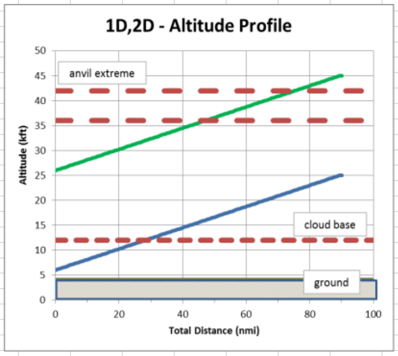


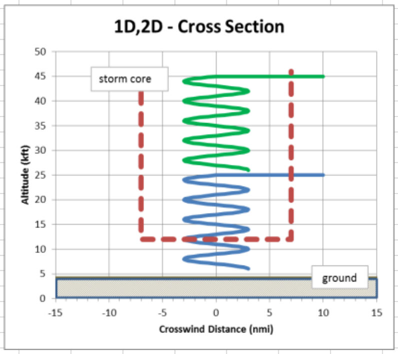




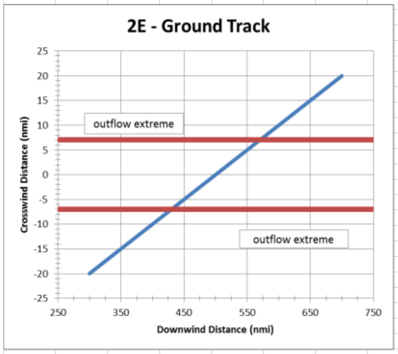
profiles: storm upwind, storm anvil, storm fresh outflow, aged outflow

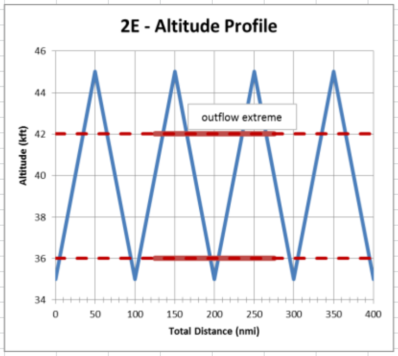


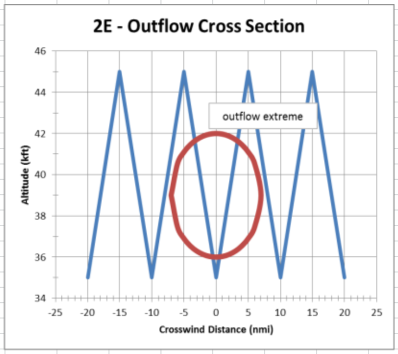




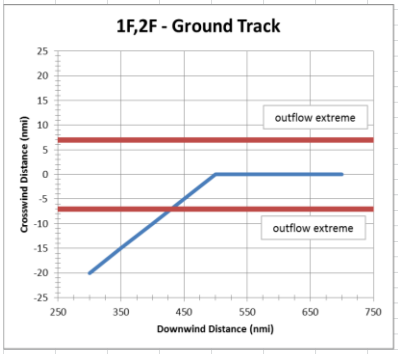
porpoise to locate aged outflow

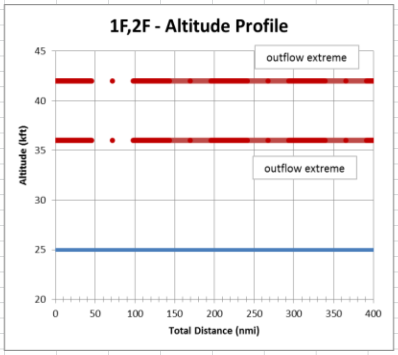


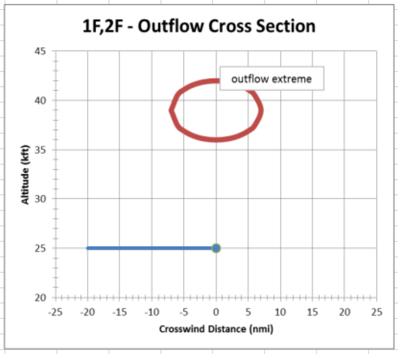




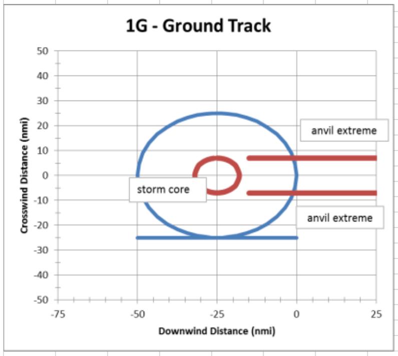
remote sensing of fresh outflow, aged outflow (DC-8)

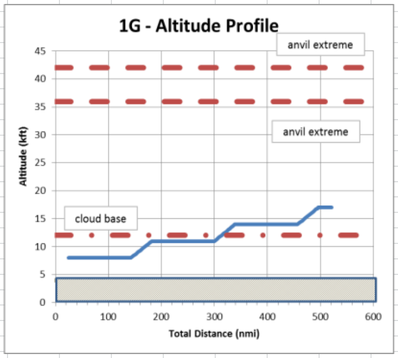


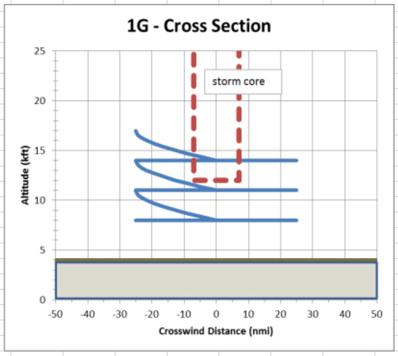




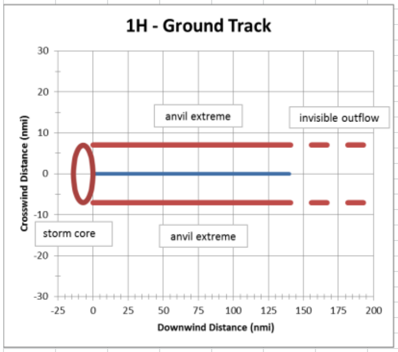
storm vicinity boundary layer and mid-latitude composition

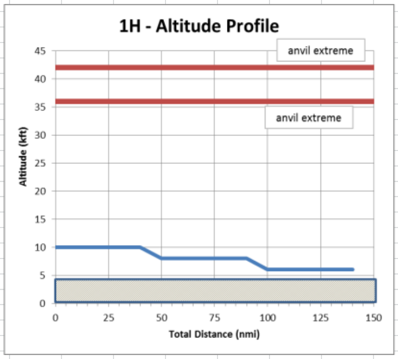


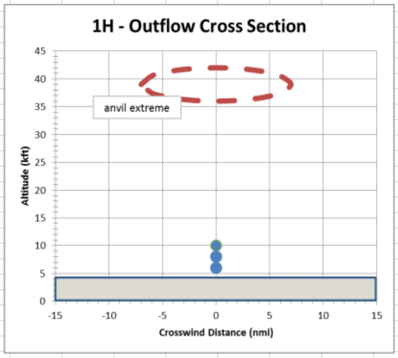




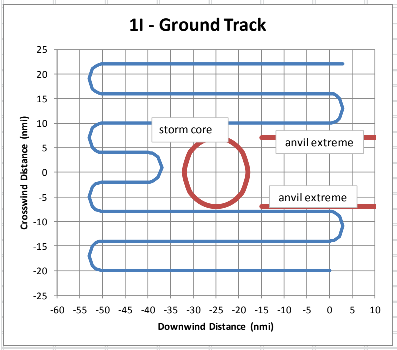
inflow profile legs

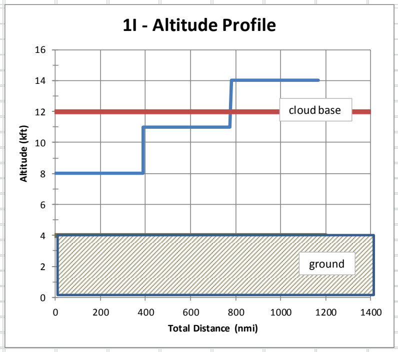


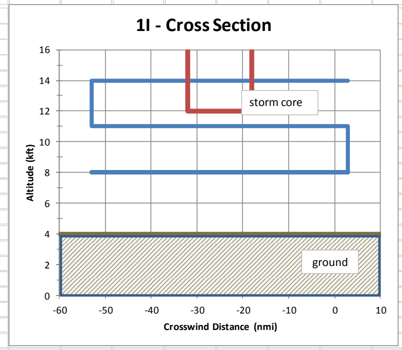




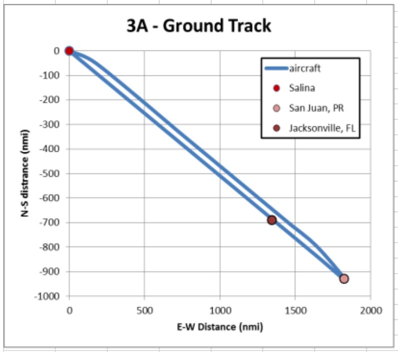
storm vicinity boundary layer and mid-latitude composition straight legs

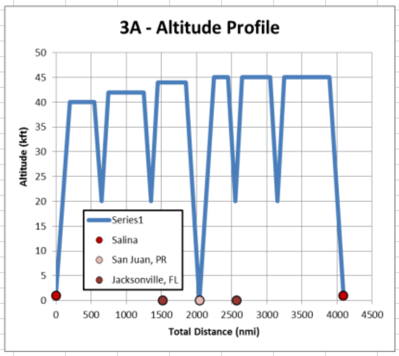




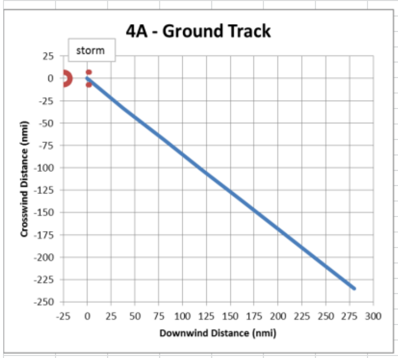


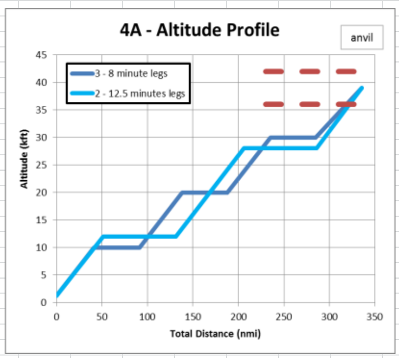
regional ozone survey - Salina to San Juan, PR (about 8.9 hours at 460 knots TAS)





intercomparison legs





Appendix F. Comparable Measurements on the three DC3 Aircraft

DC3 potential intercomparisons
22 March 2012

= 3 platforms (green)
=2 platforms (orange)

Intercomparable species	GV		DC-8		Falcon	
Ozone						
O3	FO3	O3	CSD CL DIAL HSRL	O3 O3 profiles	UV Absorption	O3
Reactive Nitrogen						
NO2	CL NOx	NO2	CSD CL TD-LIF	NO2 NO2		
NO	CL NOx	NO	CSD CL	NO	CL	NO
HNO3	GT-CIMS	HNO3	SAGA CIT-CIMS	HNO3 HNO3	CIMS	HNO3
NOy			CSD CL	NOy	CL	NOy
PAN			GT-CIMS	PANs	CIMS	PANs
			TD-LIF	ΣANs, ΣPNs		
	GT-CIMS	HNO4	CIT-CIMS	HNO4		
Carbon						
HCHO	CAMS	HCHO	DFGAS ISAF	HCHO HCHO		
CH3CHO	TOGA	CH3CHO	PTR-MS	CH3CHO		
CO	UV Fluorescence	CO	DACOM	CO	UV Fluorescence	CO
CO2	PICARRO	CO2	AVOCET	CO2	PICARRO	CO2
CH4	PICARRO	CH4	DACOM	CH4	PICARRO	CH4
CH3CN	TOGA	CH3CN	PTR-MS	CH3CN		
			CIT-CIMS	organic acids (Table 2)		
			CIT-CIMS	selected OVOCs (Table 2)		
			CIT-CIMS	isoprene hydroxynitrates, hydroxyperoxides, dihydroxyepoxides		
VOCs, OVOCs, CFCs, etc (Table 2)	TOGA	VOCs, OVOCs, CFCs	WAS PTR-MS	Hydro and halo carbons Fast OVOC and NMHC	canisters	VOCs, halocarbons
HOx and Peroxides						
Peroxides	P-CIMS	Peroxides	CIT-CIMS	Peroxides		
			ATHOS	OH, HO2		
Radiation						
Spectral Irradiance	HARP	Irradiance	SSFR	Solar and near IR Irradiance		
Actinic Flux	HARP	Actinic Flux	CAFS	Actinic flux	Filter Radiometer	J(NO2)
Broadband Irradiance	RAF-Irradiance	broadband UV, shortwave, IR	BBR	Broadband solar and IR		
Water						
H_2O vapor	VCSEL RAF-EDPC	water vapor water vapor	DLH	Water vapor		
Dew/Frost point	RAF-DPX	Dew/Frost Point temperature	X	Dew/Frost Point temperature		
	CU Total Water	total water				
Other						
SO2	GT-CIMS	SO2	GT-CIMS	SO2	CIMS	SO2
	GT-CIMS	HCl				
			CIT-CIMS	HCN		
			DACOM	N2O		
	TOGA	PFC tracer	WAS	PFC tracer	absorption tubes	PFC tracer
Cloud Droplet & Particle Size						
Particle Number, >10nm	CN	particle number, >10nm	CN	particle number, >10nm	3 x CPC	particle number, >5nm
Particle Number, >10nm, heated			CN	particle number, >10nm, heated	3 x CPC	particle number, >10 nm, non-volatile
			CN	particle number, >3nm		
Particle Size	SMPS	particle size distribution, 10-500nm	SMPS	particle size distribution, 10-300nm		
			SPEC	Aerosol parameters		
Particle Size	UHSAS	particle size distribution, 60-1000nm	UHSAS UHSAS	particle size distribution, 60-1000nm particle size distribution, dry and humidified	UHSAS-A PCASP-100X	particle size distribution 70-1000nm particle size distribution 140-1000nm
			LAS	particle size distribution, 0.1-5 um		
			APS	particle size distribution, 0.5-5um		
			DASH-SP	f(RH)		
			APR-2	clouds & precipitation		

	3V-CPI	cloud particle imaging				
	2D-C	cloud particle imaging				
Cloud Particle Size	CDP	cloud droplet size distribution	FCDP	cloud droplet size distribution	FSSP-300	size distribution 0.4-20um
					2 x Grimm OPC 1.29	size distribution 0.25-2um (total/non-volatile)
Particle Composition and Optical Properties						
			PALMS	Single particle composition		
			AMS	Aerosol mass spectra		
			Anderson-Neph	Aerosol scattering (Total, submicron), f(RH) @450, 550, 700 nm		
			Anderson-PSAP	Aerosol absorption (Total, nonvolatile) @467, 530, 660 nm		
			Brock-Filter	Total absoption @467, 530, 660 nm		
			Brock-Photoacoustic	Total (@405, 532, 660 nm), RH @ 532 (dry, 85% RH), λ dependence, BC-clear coatings (@532), BC-brown coatings (@405 nm)		
			Brock-CRD	aerosol extinction (dry @405, 532, 660 nm; wet @75%, 95% RH, λ dependence, gas-phase @405, 532, 660 nm)		
			PI-Neph	polarized phase function		
			DIAL-HSRL	aerosol backsctter profiles		
			DIAL-HSRL	depolarization profiles		
			DIAL-HSRL	aerosol extinction profiles		
			CCN	CCN number		
			Dibb-filters	bulk inorganic ions (Table 3)		
			Dibb-filters (+Weber)	organic compounds (Table 3)		
			Dibb-mist chamber	fine sulfate		
					3-lambda-PSAP	absorption coefficient
			LARGE	Aerosol measurements - includes Martin Polar Neph		
Black Carbon			HD-SP2	Black carbon aerosol, dry & wet	SP2	black carbon
Meteorology						
Winds	RAF-WINDS	wind direction & speed	MMS	wind direction & speed	X	wind direction & speed
Temperature	RAF-ATX	temperature	MMS	temperature	X	temperature
Pressure	RAF-PSXC	corrected static pressure	MMS	corrected static pressure	X	corrected static pressure
						`
39	32		66		23	

Appendix G. ReadyTalk Connection Information

To participate in DC3 meetings using ReadyTalk, use the following information:

Audio Dial-In:

- 866-740-1260
- 303-248-0285
- Access Code: 4978380

Visual via web browser:

- http://www.readytalk.com
- “Join a meeting” code: 4978380

Please mute your telephone to avoid extraneous noise.

Appendix H. DC3 and Related Websites

Project & Logistics: http://www.eol.ucar.edu/projects/dc3 or http://www.eol.ucar.edu/dc3
Science: http://www2.acd.ucar.edu/dc3
E&O: http://www.eol.ucar.edu/dc3/outreach
DC3 Field Catalog: http://catalog.eol.ucar.edu/dc3_2012/
ARM SGP: http://www.arm.gov/campaigns/sgp2012dc3

Aircraft

GV: http://www.eol.ucar.edu/projects/dc3/logistics/gv/
DC-8: http://www.nasa.gov/centers/dryden/news/FactSheets/FS-050-DFRC.html
Falcon: http://www.dlr.de/fb/en/desktopdefault.aspx/tabid-3714/

Ground Facilities

Colorado

CHILL: http://www.chill.colostate.edu
MISS: http://www.eol.ucar.edu/instrumentation/sounding/iss/mobile-iss-miss
CO LMA: http://lightning.nmt.edu/colma and http://lightning.nmt.edu/colma/current/

Oklahoma/Texas

SMART-R: http://www.nssl.noaa.gov/smartradars/
KOUN: http://wdssii.nssl.noaa.gov/web/wdss2/products/radar/koun.shtml
OU PRIME: http://arrc.ou.edu/ouprime/
MPAR: http://www.nssl.noaa.gov/divisions/radar/par/mpar.php
NOXP: http://wdssii.nssl.noaa.gov/web/wdss2/products/radar/NOXP.shtml
OK LMA: http://lightning.nmt.edu/oklma/ , http://lightning.nmt.edu/oklma/anim/
OK Mesonet: http://www.mesonet.org
TX LMA: http://pogo.tosm.ttu.edu/wtlma/current/current_density.html ,
http://pogo.tosm.ttu.edu/wtlma
TX Mesonet: http://www.mesonet.ttu.edu/

Alabama

ARMOR: http://nsstc.uah.edu/ARMOR/index.html
MAX: http://vortex.nsstc.uah.edu/mips/max/
MIPS: http://vortex.nsstc.uah.edu/mips/
AL LMA: http://branch.nsstc.nasa.gov/cgi-bin/LMA.pl ,
http://branch.nsstc.nasa.gov/PUBLIC/NALMA/

LMA video: http://www.youtube.com/watch?v=gSj0X3nOVk4

EOL Software: http://www.eol.ucar.edu/data/software
aeros: http://www.eol.ucar.edu/raf/Software/aeros_dnld.html
n2asc: http://www.eol.ucar.edu/raf/Software/n2asc_dnld.html

TIIMES (defunct): http://utls.tiimes.ucar.edu/science/dc3.html

Appendix I. Maps & Diagrams

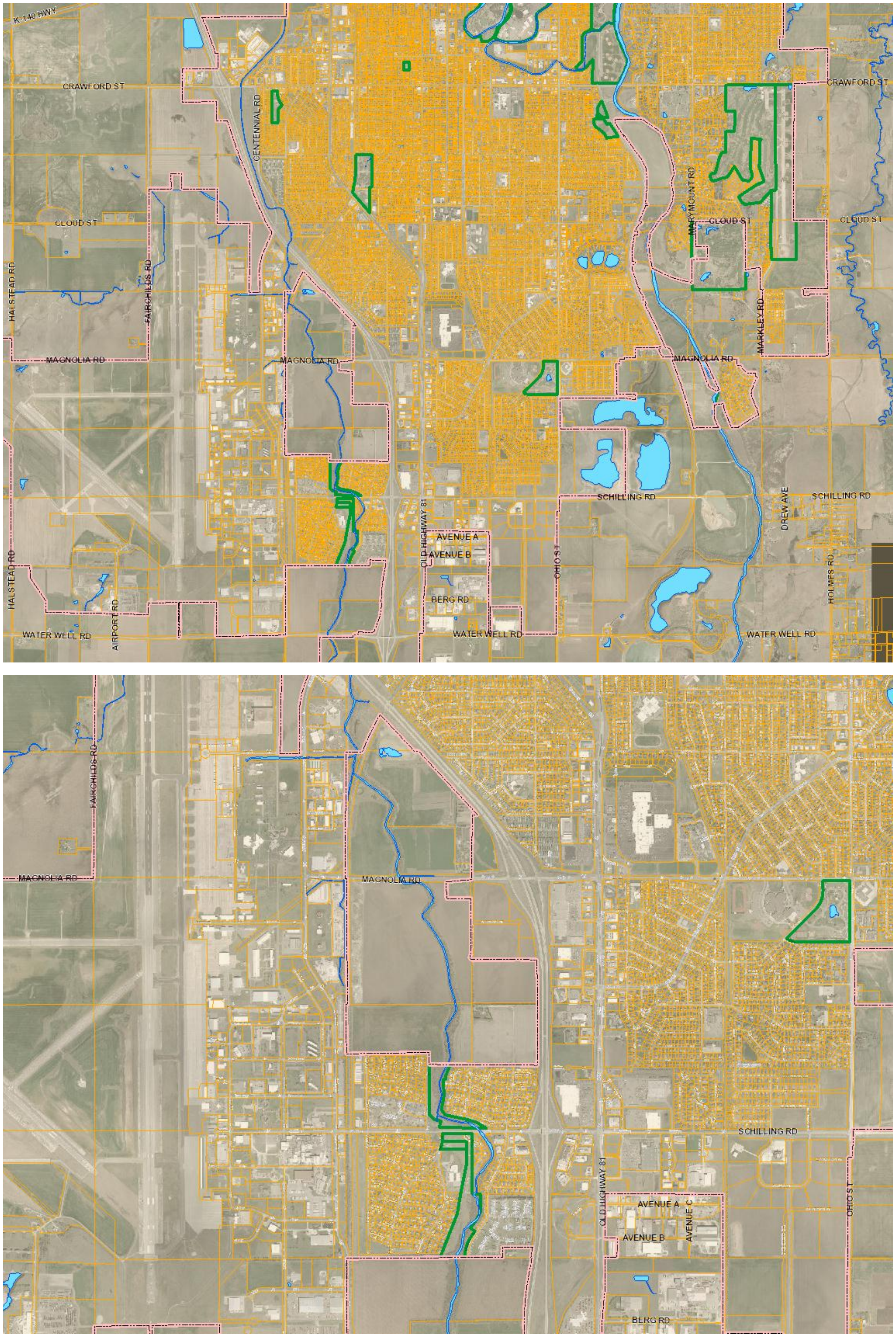


Figure I-1. Two views of Salina in the vicinity of the Salina Municipal Airport.

Figure I-2. View of Salina Municipal Airport.

Figure I-3. View of Hangars 600 (below DC-8 outline on apron) and 606 (to right of 600).

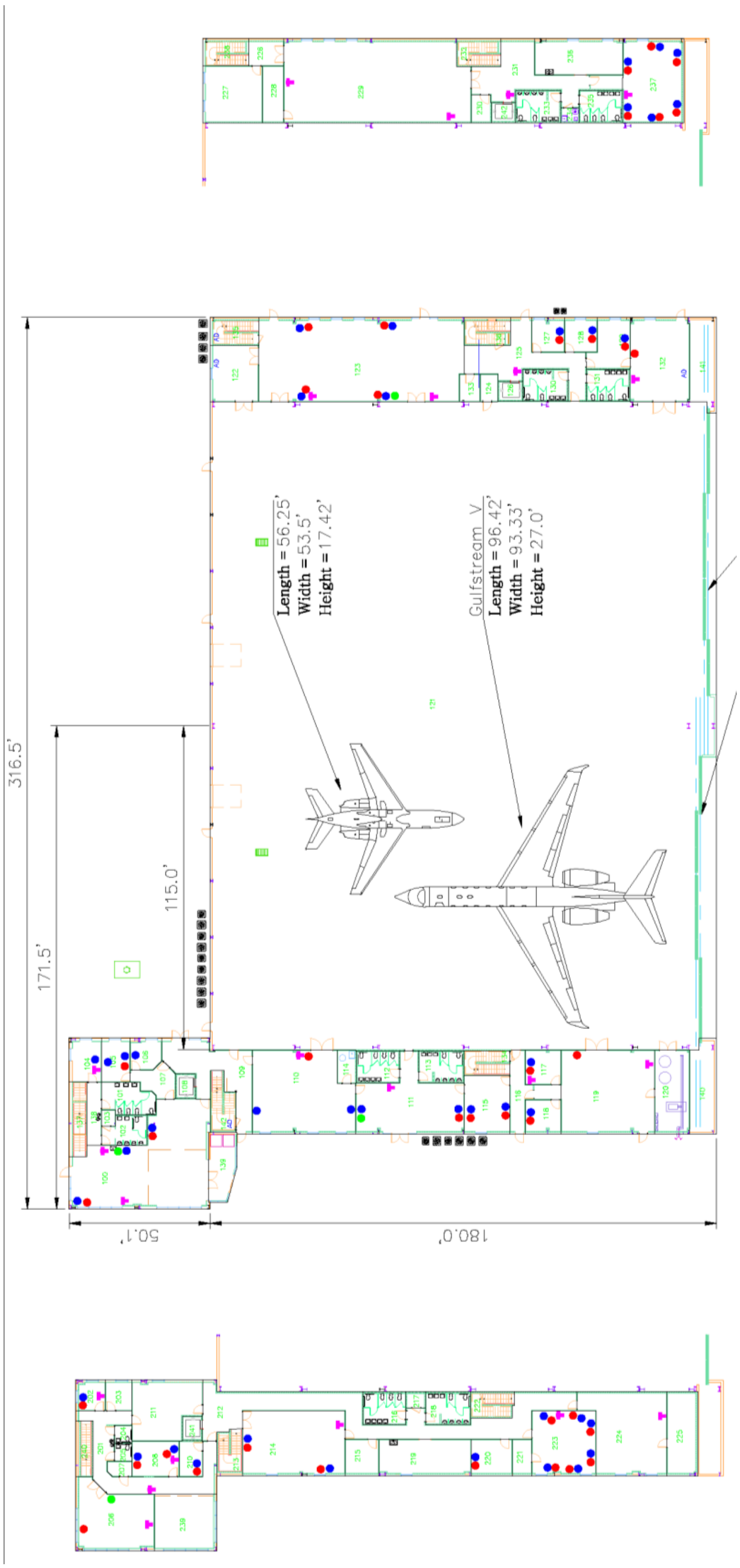


Figure I-4. View of Hangar 600 with GV and Falcon aircraft.

Appendix J. Salina Municipal Airport Rules and Regulations

Full document can be found at:
www.salinaairport.com/pdfs/FINAL%20-%20SLN%20Rules%20and%20Regs.pdf

3. GENERAL RULES AND REGULATIONS.

3.1 Abandoned, Derelict or Lost Property. Property including, without limitation, Aircraft, vehicles, equipment, machinery, baggage, or personal property shall not be abandoned on the Airport. Abandoned, derelict, or lost property found in public areas at the Airport shall be reported to the executive director. Property unclaimed by its proper owner or items for which ownership cannot be established will be handled in accordance with applicable law. Nothing in this section shall be construed to deny the right of operators and other lessees to maintain "lost and found" service for property of their customers and/or employees.

3.2 Accidents or Incidents. In addition to other appropriate notifications and actions, accidents resulting in damage to property, injury requiring medical treatment, or interference with normal Airport operations shall be promptly reported to the executive director, in addition to other appropriate notifications.

3.3 Airport Liability. The Airport Authority and the City of Salina, Kansas, and their agents or employees shall not be liable for loss, damage or injury to persons or property arising out of any accident, incident or mishap of any nature whatsoever and/or from any cause whatsoever and/or from any cause whatsoever to any individual, aircraft, or property occurring on the Airport, or in the use of any of the Airport Authority facilities.

3.4 Airport Operations. The executive director, or his designee, may delay, restrict, or prohibit, in whole or in part, any operations at the Airport for any justifiable reason.

3.5 Animals. Domestic pets and animals, except animals required for assistance or law enforcement dogs, are not permitted on the AOA of the Airport or in the Airport passenger terminal building, unless being transferred or shipped, and then only if controlled and restrained by a leash, harness, restraining strap, portable kennel, or other appropriate shipping container. Leashes, harnesses and straps shall not exceed six (6) feet. It shall be the responsibility of the owner or handler to exercise control over the animal at all times. Owners or handlers are responsible for the immediate removal and disposal of animal waste. No person, except those authorized in writing by the executive director shall intentionally hunt, pursue, trap, catch, injure, or kill any bird or animal on the Airport. Feeding or otherwise encouraging the congregation of birds or animals on the Airport is prohibited.

3.6 Buildings and Remodeling. It shall be unlawful for any person, other than the Authority, to construct, reconstruct or remodel any building or other improvement on the Airport without first obtaining written permission from the Authority and applicable permits from the City of Salina. Any changes, alterations, or repairs made without proper approval, and any damage resulting therefrom shall be paid for by the person responsible and in accordance with the direction of the Authority.

3.7 Commercial Activities. Commercial activity of any kind on the Airport requires the express written permission of the Authority through a specifically authorized lease, sublease, license, permit or written temporary permission, and upon such terms and conditions as they may prescribe, and the payment of any required fees. Unless otherwise provided in such document, any permission may not be assigned or transferred and shall be limited solely to the approved activity.

3.8 Compliance with Regulatory Measures. All persons occupying or using, engaging in an aeronautical activity on, or developing Airport land or improvements shall comply, at the person's or entity's sole expense, with all applicable regulatory measures including, without limitation, the Salina Municipal Airport Minimum Standards, these Rules, and those of the federal, state, and local government and any other agency having jurisdiction over the Airport.

3.9 Damage to Airport Property. Any and all Airport property, real or personal, and/or facilities destroyed, broken, or damaged by accident or otherwise shall be paid for by the person responsible for the damage. Aircraft equipped with tail or landing skids or other devices, which will damage pavement or sod areas shall not be operated on the Airport.

3.10 Fire/Open Flames. Open flames of any kind are prohibited except (a) as provided in a burn permit; or (b) for open flames utilized by operators/lessees in the performance of approved aircraft maintenance. Burn permits may be issued in the discretion of the Salina Fire Department and only in compliance with applicable building and/or fire codes. Smoking and the use of any open-flame device is prohibited on any apron, or within fifty (50) feet of any aircraft, fuel truck, fueling facility, or other flammable storage facility. Any fires (regardless of the size of the fire or whether or not the fire has been extinguished) shall be reported immediately to 911. No welding/cutting activities shall be conducted on the Airport without an approved fire extinguisher and a person trained in its proper usage present for the duration of any welding/cutting activities.

3.11 Firearms. No persons, except law enforcement officers on official duty, authorized federal agents on official duty, airport employees authorized by the executive director for wildlife hazard reduction purposes, members of the Armed Forced of the United States on official duty, and authorized foreign armed forces on official duty, shall carry any firearms or any explosives on Airport property. Unloaded and properly secured firearms may be stored as cargo for travel on Airport property.

3.12 General Conduct. No person shall use or otherwise conduct himself upon any portion of the Airport in any manner contrary to any posted or otherwise visually indicated directions applicable to that area. Overnight camping or lodging on the Airport is prohibited. Except for the Airport fire station, use of any facility on, or area of, the Airport for sleeping or other purposes in lieu of a hotel, motel, residence or other public accommodation is prohibited. No person shall use, keep, or permit to be used or kept, any foul or noxious gas or substance at the Airport, or permit the Airport to be occupied or used in a manner offensive or objectionable to other users for any reason. Spitting on, marking, or defacing the floors, walls, or other surface of the Airport is prohibited.

3.13 Hazardous Materials. No person shall cause or permit any hazardous material to be used, generated, manufactured, produced, stored, brought upon, or released, on, under or about any premises, or transported to and from the Airport, by itself, its agents, employees, contractors, invitees, sublessees or any third party in violation of any environmental law, provided that, in no circumstances shall any person or entity cause or permit any extremely hazardous substance or toxic chemical to be used, generated, manufactured, produced, stored, brought upon, or released, on, under or about the Airport, or transported to and from any premises. All persons or entities shall promptly notify the Airport of any action or condition that is contrary to any prohibition in the previous sentence. Approved hazardous material must be stored in suitable containers that are properly secured. Material Safety Data Sheets (MSDS) for all hazardous materials shall be maintained on site so as to be readily available to emergency responders in the event of an emergency and for review by the Salina Fire Department. No fuels, oils, dopes, paints, solvents, acids, or any other hazardous material shall be released in storm water conveyances, drains, catch basins, ditches, the AOA or elsewhere on the Airport. Tenants and operators who generate and dispose of "Special Waste" shall comply with the requirements of 40 CFR Sections 266 & 273. Special waste includes widely generated wastes such as batteries, agricultural pesticides, mercury containing devices, hazardous mercury-containing lamps, and used oil. Used engine oil shall be disposed of only at approved waste oil stations or disposal points. Secondary containment is required for the storage of gasoline, oils, solvents, or other hazardous waste in drums or receptacles. Aviation fuels or automotive gasoline in quantities greater than five (5) gallons shall not be stored at the Airport without the prior written permission of the executive director. Any fuels must be stored in accordance with any applicable codes, regulations, and requirements for the storage of volatile fuels. No hazardous substance or pollutant shall be disposed of on the Airport or into the air at the Airport during aircraft preflight inspection.

3.14 Hazardous Material Spills. Any person who experiences overflowing or spilling of oil, grease, fuel, alcohol, glycol or any other hazardous material anywhere on the Airport shall immediately call 911. Persons involved in hazardous material incidents shall take action to prevent/minimize danger to personnel, property and the environment while awaiting arrival of the Salina Fire Department personnel. At the discretion of the Salina Fire Department, the entity responsible for the spill may be required to clean and properly dispose of the material/substance which shall be performed in compliance with all applicable federal, state, and local regulations and guidelines. In addition, the entity may be required to provide the Salina Fire Department with required documentation of proper disposal. Any costs incurred by the Authority or Salina Fire Department in such instances shall be reimbursable to the Authority and/or the Salina Fire Department by the person responsible for the spill.

3.15 Licenses, Permits, Certifications and Ratings. Operators shall obtain and comply with all necessary licenses, permits, certifications, or ratings required for the conduct of operator's activities at the Airport as required by the executive director or any other duly authorized agency prior to engaging in any activity at the Airport. Upon request, operators shall provide copies of such licenses, permits, certifications, or ratings to the Airport within 5 business days. Operators shall keep in effect and post in a prominent place all necessary or required licenses, permits, certifications, or ratings.

3.16 Painting. Doping processes, painting, or paint stripping shall be performed only in those facilities approved for such activities by the executive director and in compliance with air quality regulations, the Fire Code, and the Authority's Storm Water Pollution Prevention Plan (SWPPP), and 14 CFR Part 43.

3.17 Preservation of Property. No person shall destroy or cause to be destroyed, injure damage, deface, or disturb, in any way, property of any nature located on the Airport. Any person causing or responsible for such injury, destruction, damage or disturbance to Airport-owned property shall report such damage to the executive director and shall reimburse the Airport the full amount of repair and replacement of property. No Person shall take or use any aircraft, aircraft parts, instruments, tools owned, controlled, or operated by any person while on the Airport or within its hangars, except with the consent of the owner or operator thereof. No person shall prevent the lawful use and enjoyment of the Airport by others. Any activity which results in littering, environmental pollution or vandalism on the Airport is not permitted and violators are subject to arrest.

3.18 Signage/Advertisements. Written advertisements, signs, notices, circulars, and/or handbills may be posted or distributed only with the prior written permission of the executive director. The Airport has the right to remove any such sign, placard, picture, advertisement, name or notice in any such manner as the Airport may designate. No signage may be installed on the Airport without the prior written approval of the executive director.

3.19 Solicitation, Picketing, and/or Demonstrations. Airport users shall comply with any Airport policy regarding solicitation, demonstration, or the distribution of literature on the Airport.

3.20 Sound Amplifying Devices. Sound amplifying devices such as megaphones, public address systems, or any other device designed to amplify and broadcast the human voice over a distance are prohibited on the Airport unless written approval from the Executive Director is given prior to their installation and use.

3.21 Special Events. Special events on the Airport require written coordination, regulation and authorization of the executive director prior to the public disclosure or advertisement of the event. Certain events may require an executed lease, operating agreement or permit with the executive director.

3.22 Through-the-Fence Activities. All "Through-the-Fence" activities may be conducted only in accordance with written agreement with the City. No such "Through the Fence" activity shall be authorized except in strict accordance with the Authority's Minimum Standards.

3.23 Trash and Other Waste Containers. No person shall dispose of garbage, paper, refuse or other materials on the Airport except in receptacles provided for that purpose. The executive director shall designate areas to be used for garbage receptacles and no other areas shall be utilized. Tenants, operators and other users of the Airport shall not move or otherwise re-locate Airport-placed trash and waste containers. Garbage, empty boxes, crates, rubbish, trash, papers, refuse, or litter of any kind shall not be placed, discharged, or deposited on the Airport, except in the receptacles provided specifically for that purpose. The burning of garbage, empty boxes, crates, rubbish, trash, papers, refuse, or litter of any kind on the Airport is prohibited. Trash and other waste containers at the Airport shall only be used for trash generated on Airport property. Trash and other waste container areas shall be kept clean and sanitary at all times. Tenants and operators shall ensure that their trash and waste containers are emptied with sufficient frequency to prevent overflowing, shall be cleaned with sufficient frequency to prevent the development of offensive odors, and are equipped with securely fastened lids which shall be closed and fastened at all times other than while the receptacles are being loaded or unloaded.

3.24 Use of Roadways and Walkways. No person shall travel on the Airport other than on the roadways, walkways, or other areas provided for the particular class of traffic, or occupy roadways or walkways in such a manner as to hinder or obstruct their proper use. No person shall operate any type of vehicle on the roads or walks except as designated by the executive director.

3.25 Wildlife Hazard Reduction. The executive director, and his designee, are authorized to use FAA approved wildlife hazard reduction techniques including, but not limited to, discharge of firearms on Airport property. Use of lethal reduction techniques will comply with FAA guidelines, Kansas Department of Wildlife and Parks and Federal permit and tag requirements, and will be accomplished by personnel who are trained in the use of firearms and who have an excellent knowledge of wildlife identification. The proper gun and ammunition will be used for the situation. The location in which wildlife reduction techniques will be used should be examined for safety purposes. Firearms should be discharged in a safe manner away from people and property to avoid injury.

4. SECURITY AND SAFETY.

Scheduled air carrier and public charter air carrier aircraft operators using the Airport are subject to the Airport Security Program, as may be amended from time to time. Persons in violation of TSA, FAA and/or Airport security rules, including those set forth herein and elsewhere, may be denied access to the Airport, may have access or driving privileges revoked, and/or may be fined or otherwise penalized in accordance with applicable regulatory measures. Operators who are required to provide controlled access to their facilities and/or aircraft for security reasons are responsible for ensuring that all personnel are trained on the appropriate procedures for authorizing non-employees and passengers access to their respective facilities and/or aircraft.

4.1 Restricted or Secure Areas. Restricted or secure areas on the Airport are those areas that are identified in the ASP as areas where no person is allowed access unless issued Airport identification that is recognized in the ASP.

4.1.1 No person shall enter any restricted or secure area except those persons directly engaging in work or an aviation activity that must be accomplished therein; and

4.1.1.1 Having prior authorization of the Authority or under appropriate supervision or escort; or

4.1.1.2 Employed by or representing the FAA, TSA, DHS, or recognized in the ASP as being authorized to access to certain secured areas of the Airport.

4.1.2 No person shall cause any object to be located within eight (8) feet of the Airport perimeter fence, which may assist an unauthorized individual in accessing a secure area.

4.1.3 Any gate or fence condition that would allow unauthorized access to restricted or secure areas of the Airport must be reported immediately to the executive director. Any attempts by any persons to gain unauthorized access to any such area, and any conditions that would adversely affect the safety or security of aircraft operations shall be reported immediately to the Salina Police Department and the executive director.

4.1.4 Any person who violates security related regulatory measures may be denied future entry into a restricted or secure area.

4.1.5 All persons shall wear and visibly display their approved Airport identification recognized in the ASP on their outermost garment, waist or higher, while inside a secure area.

4.1.6 Airport identification holders must notify the executive director of any entry or attempted entry to a secure area by any unauthorized person, or by any unauthorized means.

4.1.7 Any person with proper Airport identification as required by the ASP may bring a person without proper Airport identification into a secure area if the person has a valid reason for being inside the secure area and if the person is provided continuous escort by a person with proper Airport identification. A continuous escort requires that the escorted person remains in close proximity to the Airport identification holder at all times while inside the secure area. The Airport identification holder shall bear full responsibility for the actions of the person being escorted.

4.2 Sterile Area. Any persons desiring to enter a sterile area are subject to security screening.

4.3 Security Access.

4.3.1 Security gates (pedestrian or vehicular) that provide access to the AOA shall be kept closed and locked at all times, except when actually in use. All access gates to the AOA through a tenant's leased premises are Operator's/lessee's responsibility and shall be monitored and secured in a manner that will prevent unauthorized access.

4.3.2 Vehicle operators shall stop their vehicle and allow the gate to fully close before proceeding, and shall also ensure that no other vehicles or persons gain access to the Airport while the gate is in the process of closing or not fully closed. If the vehicle operator cannot prevent such access, the vehicle operator shall immediately notify the executive director and the Salina Police Department.

4.3.3 Tampering with, interfering with, or disabling the lock, or closing mechanism or breaching any other securing device at the Airport is prohibited.

4.3.4 Persons who have been provided either a code or a device for the purpose of obtaining access to the AOA shall not divulge, duplicate, release, or otherwise distribute the same to any other person.

4.3.5 Persons with authorized access to the AOA may escort an unauthorized vehicle directly to and from the immediate area around the aircraft hangar for the purpose of loading and unloading. The person with authorized access is responsible for insuring compliance with the Rules and Regulations.

Appendix K. Acronyms

2D-S –particle imager at 2 orthogonal views
ARCTAS – Arctic Research of the Composition of the Troposphere from Aircraft and Satellites, 2008 (http://www.nasa.gov/mission_pages/arctas/)
ARM – Atmospheric Radiation Measurement network
ARMOR – Advanced Radar for Meteorological and Operational Research, located at Huntsville International Airport (http://nsstc.uah.edu/ARMOR/index.html)
AWAS – Advanced Whole Air Sampler
CALIOP – Cloud-Aerosol LIdar with Orthogonal Polarization aboard the CALIPSO platform
CALIPSO – Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (http://www-calipso.larc.nasa.gov/)
CASA - Center for Collaborative Adaptive Sensing of the Atmosphere
CPI – particle imager at 8-bit gray levels
CRYSTAL-FACE – Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment, 2002 (http://www.espo.nasa.gov/crystalface/index.html)
CSU-CHILL – Colorado State University advanced transportable dual-polarized S0-band weather radar system (http://www.chill.colostate.edu)
CSU-Pawnee – Colorado State University single-polarization radar system (http://www.chill.colostate.edu)
DFW – Dallas – Ft. Worth International Airport
DIA or DEN – Denver International Airport
DLR – German Aerospace Center (Deuches Zentrum fuer Luft- und Raumfahrt) (www.dlr.de/en/)
DOE – Department of Energy (http://www.energy.gov/)
EOL – NCAR Earth Observing Laboratory (http://www.eol.ucar.edu/)
ESPO – Earth Science Project Office (http://www.espo.nasa.gov/)
EULINOX – European Lightning Nitrogen Oxides Project, 1998 (http://www.pa.op.dlr.de/eulinox/)
FAA – Federal Aviation Administration
FPS – NCAR/EOL Field Project Services (http://www.eol.ucar.edu/fps.html)
GTCIMS – Georgia Tech Chemical Ionization Mass Spectrometer
HAIS – HIAPER Aircraft Instrumentation Solicitation
HALO – High Altitude and LOng range research aircraft (http://www.halo.dlr.de/)
HARP – HIAPER Atmospheric Radiation Package
HIAPER – High-performance Instrumented Airborne Platform for Environmental Research (http://www.hiaper.ucar.edu)
HSV – Huntsville International Airport (http://www.hsvairport.org)
INTEX-NA – Intercontinental Chemical Transport Experiment – North America (http://www.espo.nasa.gov/intex-na/)
KCYS – NEXRAD radar near Cheyenne, Wyoming
KFTG – NEXRAD radar near Denver, Colorado
KOUN – NSSL NEXRAD radar near Norman, Oklahoma
KTLX – NEXRAD radar near Oklahoma City, Oklahoma
LDAR II – Lightning Detection and Ranging system in the Dallas-Ft. Worth area
LIDAR – Light Detection and Ranging
LMA – Lightning Mapping Array
M3V – Mobile Meteorological Measurements Vehicle
MAX – Mobile Alabama X-band polarimetric radar
MC3E – DOE-ARM NASA-GPM Midlatitude Continental Convective Clouds Experiment (http://campaign.arm.gov/mc3e/ , http://gpm.nsstc.nasa.gov/mc3e/)
MIPS – Mobile Integrated Profiling System (http://ghrc.msfc.nasa.gov:5721/dataset_documents/c4gmipwp_dataset.html)
MISS – Mobile Integrated Sounding System (http://www.eol.ucar.edu/instrumentation/sounding/iss/mobile-iss-miss)
MPAR – Multi-Mission Phased Array Radar (http://www.nssl.noaa.gov/divisions/radar/par/mpar.php)
MSFC – Marshall Space Flight Center (http://www.nasa.gov/centers/marshall/home/index.html)
MTP – Microwave Temperature Profiler (http://mtp.jpl.nasa.gov)
NASA – National Aeronautics and Space Administration (http://www.nasa.gov)
NCAR – National Center for Atmospheric Research (http://www.ncar.ucar.edu/)

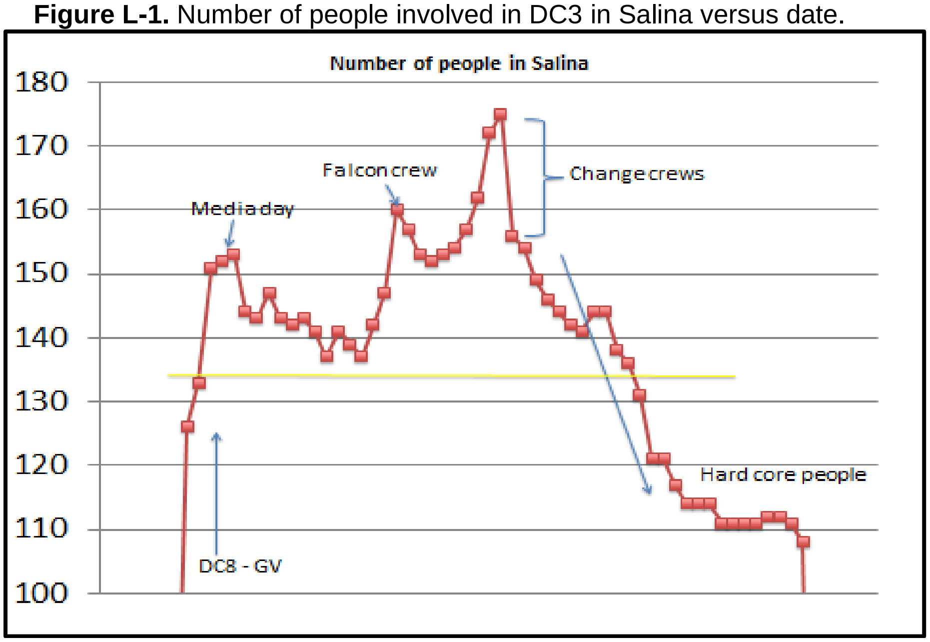
NEXRAD – Next Generation Radar network operated by National Weather Service, technically termed WSR-88D (http://www.roc.noaa.gov/)
NLDN – National Lightning Detection Network (http://www.lightningstorm.com/)
NOAA – National Oceanic and Atmospheric Administration (http://www.noaa.gov/)
NO-XP – Mobile X-Band dual polarization radar
NPOESS – National Polar-orbiting Operational Environmental Satellite System (http://www.ipo.noaa.gov/)
NSF – National Science Foundation (http://www.nsf.gov)
NSSL – National Severe Storms Laboratory operated by NOAA (http://www.nssl.noaa.gov)
NWS – National Weather Service (http://www.weather.gov/)
OCS – Oklahoma Climatological Survey (http://climate.ok.gov/)
OKLMA – Oklahoma Lightning Mapping Array network (http://www.nssl.noaa.gov/observations/ltmap.php)
OU – University of Oklahoma;
PEM-Tropics B – Pacific Exploratory Mission in the Tropics Phase B (http://www-gte.larc.nasa.gov/pem/pemtb_hmpg.htm)
QCLSH – Quantum Cascade Laser Spectrometer for HIAPER
RAF – NCAR/EOL's Research Aviation Facility (http://www.eol.ucar.edu/about/our-organization/raf)
RDCC – Real-time Display and Coordination Center (http://www.eol.ucar.edu/rdp/services/RDCC_whitepaper.htm)
SID-2H – Small Ice Detector, Version 2
SLN – Salina Municipal Airport (http://www.salinaairport.com)
SMART-R – Shared Mobile Atmospheric Research and Teaching Radar (http://www.nssl.noaa.gov/smartradars/)
START08 – Stratosphere-Troposphere Analysis of Regional Transport, 2008 (http://www.acd.ucar.edu/start/)
STERAO – Stratosphere-Troposphere Experiments: Radiation, Aerosols and Ozone, 1996 (http://box.mmm.ucar.edu/science/sterao/sterao.html)
TOGA – Trace Organic Gas Analyzer
TRACE-P – TRAnsport and Chemical Evolution over the Pacific,2001 (http://hyperion.gsfc.nasa.gov/Missions/TRACEP)
UAH – University of Alabama, Huntsville
WSR-88D – Weather Surveillance Radar, 1988, Doppler; the technical name for NEXRAD network
WTLMA – West Texas Lightning Mapping Array network

Appendix L. Other Documents

Table L-1. Conversion of altitude measurement units and ISA P & T.

km	kft	ISA P(mB)	ISA T(°C)
0.00	0	1013.2	15.5
0.61	2	942.0	10.7
1.22	4	875.0	6.5
1.83	6	811.9	2.8
2.44	8	752.6	-0.7
3.05	10	696.9	-4.3
3.66	12	644.5	-8.0
4.27	14	595.4	-11.9
4.88	16	549.3	-15.9
5.49	18	506.1	-20.2
6.10	20	465.6	-24.6
6.71	22	427.8	-29.1
7.32	24	392.6	-33.6
7.92	26	359.7	-37.9
8.53	28	329.1	-42.1
9.14	30	300.6	-45.9
9.75	32	274.3	-49.2
10.36	34	249.9	-52.1
10.97	36	227.4	-54.4
11.58	38	206.7	-56.5
12.19	40	187.7	-56.5
12.80	42	170.4	-56.5
13.41	44	154.6	-56.5
14.02	46	140.2	-56.5
14.63	48	127.3	-56.5
15.24	50	115.6	-56.5
15.85	52	105.2	-56.5

Figure L-1. Number of people involved in DC3 in Salina versus date.



Appendix M. Safety Plan for UV DIAL Airborne Lidar Operations

Non-Ionizing Radiation Safety Plan

for

UV DIAL Airborne Lidar Operations for Atmospheric Science Field Studies

April 2011

1. Background

NASA Langley operates an ozone Differential Absorption Lidar (DIAL) system on the NASA- DC-8 aircraft as part of atmospheric science field missions. This instrument provides high priority measurements that are mission critical to most of the airborne science missions. Specific field campaign details are provided several months before the mission which includes the location and duration of operations. This has included both operations in the United States and international operations.

This laser safety plan provides the laser operation and safety procedures that are implemented during deployment on the NASA DC-8, which includes both ground tests and flight operations. These procedures cover all operating locations and flight scenarios from the NASA DC-8 aircraft. During flight the ozone DIAL system will be operated in both the zenith and nadir directions from the NASA DC-8 using multi-wavelength laser outputs to measure profiles of ozone and aerosol parameters above and below the aircraft.

The DIAL system developed at NASA Langley in the Lidar Applications Group has been previously flown on several NASA planes including the NASA Electra, P-3B and DC-8 aircraft in over 30 major field campaigns since the early 1980's. The most recent missions for this instrument on the DC-8 were the ARCTAS campaign mainly operating in North America based in Palmdale CA, Fairbanks AK, and Cold Lake, AB Canada.

2. Areas of Operation

The base of operations for each mission will be specified during mission planning and with the Science Team several months before the beginning of the deployment. This safety plan includes operation of the DIAL instrument for either United States based operations and international operations. Flight altitudes and duration will be based on the specific science objectives of each flight but covers altitudes from 300 ft AGL to 42000 ft AGL and durations of up to 12 hours. This safety plan may be submitted to other organizations and government officials requesting operational procedures.

3. Proposed Schedule

The period of the airborne operations is ongoing and this laser safety plan will be reviewed annually and submitted annually to the FAA for obtaining a letter of non-objection for airborne operations. If changes to the DIAL system are made this permit will be updated and reviewed to include those changes. If the changes effect the parameters submitted to the FAA an new letter will be obtained.

4. Lidar Personnel

The following personnel are NASA Langley Research Center (LaRC) or Science Services and Applications, Inc (SSAI) laser certified workers who will be working with the airborne ozone DIAL system during operation on the NASA DC-8.

Hair, Johnathan	Research Scientist	NASA LaRC
Syed Ismail	Research Scientist	NASA LaRC
McClung, Paul E.	Electronics/Laser Technician	NASA LaRC
Butler, Carolyn	Lead Data Acquisitions Specialist	SSAI

Notari, Anthony	Lidar System Research Engineer	NASA LaRC
Kooi, Susan	Data Acquisition Specialist	SSAI
Burton, Sharon	Data Acquisition Specialist	SSAI
Collins, James	Engineer	SSAI

5. Designated Laser Safety Officer

Johnathan Hair (757-864-1406) and Syed Ismail (757-864-2719), or their designated alternate will be responsible for the overall lidar system safety and will be the primary contacts for interfacing with the mission manager during the period of operation on the DC-8.

6. System Configuration

The ozone DIAL system includes four Big Sky pulsed Nd:YAG lasers and two Continuum dye lasers to produce the wavelengths to measure ozone. The pulse repetition frequency (PRF) is 40 Hz by interleaving two pairs of Big Sky pump lasers. The fundamental wavelength of the Nd:YAG lasers is 1064 nm and has a maximum output energy of 0.8 J/pulse. The Nd:YAG lasers are frequency doubled to 532 nm with a maximum energy of 400 mJ/pulse. The second harmonic (532 nm) is used to pump the dye laser, which produce outputs at 582 and 600 nm in the visible spectrum from the two dye lasers with output energies of approximately 60-100 mJ each at 40 Hz. The dye laser outputs are frequency doubled to give UV wavelengths near 291 and 300 nm with maximum output energies of 30 mJ each at 40 Hz and are split equally into the nadir and zenith directions. These UV wavelengths (291, 300 nm) are transmitted into the atmosphere. The system uses the 291 and 300 nm beams as the "on-line" and "off-line" wavelengths, respectively, for the DIAL technique to measure tropospheric and lower stratospheric ozone. The on- and off-line Nd:YAG lasers are pulsed approximately 300 s apart to allow both sets of laser beams to sample the same atmospheric region. The UV beams are split 50/50 between the zenith and nadir.

A second Fibertek Inc custom built laser which is frequency doubled and frequency tripled provides three output wavelengths that are used for aerosol and cloud profile measurements. The pulse repetition rate of this laser is 200 Hz. There are two separate channels in the laser that provide output beams at all three wavelength (355nm, 532nm, 1064nm). One channel is used for the zenith transmission and the other is used for the nadir transmission. The maximum output energy in each beam is 30mJ at the wavelengths (i.e. 30mJ-355nm, 30mJ-532nm, 30mJ-1064nm).

These UV wavelengths (291, 300 nm) are transmitted into the atmosphere. The system uses the 291 and 300 nm beams as the "on-line" and "off-line" wavelengths, respectively, for the DIAL technique to measure tropospheric and lower stratospheric ozone. The on- and off-line Nd:YAG lasers are pulsed approximately 300 □s apart to allow both sets of laser beams to sample the same atmospheric region. The UV beams are split 50/50 between the zenith and nadir. The atmospheric backscatter from the five nadir and five zenith beams is collected by two telescopes. The received range-resolved signal is digitized, recorded, and analyzed for ozone, and aerosol scattering ratios for all transmitted wavelengths. Real-time color images of aerosol and ozone distributions are produced on the DC-8 that are used to help guide the aircraft flight for optimal sampling of chemical and dynamical processes under investigation.

All beams that are transmitted in the atmosphere from airborne or ground based operations are always along the zenith or nadir directions. The system has no scanning capability.

Table 1 below provides the *maximum transmitted* output energies, wavelength, and pulse repetition frequency of the DIAL system. Note that the visible and NIR (532 nm, 1064 nm) beams are expanded to a larger divergence to decrease the NOHD.

Table 1. Transmitted laser wavelengths, energies, PRF, and laser divergence

Zenith Transmission			
nm	**mJ**	**Hz**	**mrad**
1064	30	200	1.0
532	30	200	1.0
355	30	200	0.5
300	15	40	0.5
288	15	40	0.5

Nadir Transmission			
nm	**mJ**	**Hz**	**mrad**
1064	30	200	1.5
532	30	200	1.0
355	30	200	0.5
300	15	40	0.5
291	15	40	0.5

7. Eye Safety Plan

A. Laser Controlled Area

During airborne lidar field operations the laser controlled area is considered to be the vicinity immediately surrounding the lidar system on the aircraft. Laser safety signs will be posted at each end of the DIAL system in the DC-8 along with laser curtains placed around the lasers in the system to contain the laser beams when diagnostics and alignments on the lasers are required. Only laser certified personnel will be allowed to enter behind the curtains with proper eye safety protection when the laser is in operation. A light will be used at the entrance of the aircraft to indicate laser operation on the aircraft for additional warning to crew members.

B. Enclosed Beam Path

The airborne lidar system is designed to completely enclose all laser beams until they reach the aircraft windows where they are transmitted out of the plane. During beam alignment and laser diagnostic measurements, the laser enclosures will be opened to allow access to the beams. In this situation, the beams are still contained within the barrier curtain previously mentioned. If the laser beam is not totally enclosed then proper eye safety glasses will be worn by all certified personnel that are behind the barrier curtain. The laser beam will always be blocked at the shortest distance possible when the beams are not totally enclosed. The curtains will be opened only when all the laser output beams are totally enclosed to the exit ports of the aircraft. In addition, the side windows of the aircraft will be blocked to prevent any diffuse scattered laser light from exiting the aircraft.

8. Eye Safety Calculations and Procedures

The lidar eye safety calculations are based on the maximum permissible exposure (MPE) as defined by the American National Standards Institute (ANSI) Z136.1 standard for the safe use of lasers and the FAA Aircraft Circular AC 70-1 (Dec 2004). MPE is a function of wavelength, viewing conditions, pulse length, power and tissue exposed. By incorporating the MPE values for intrabeam viewing and calculating the radiant exposure at ground level, one can insure that the beams are eye safe to a ground observer for any aircraft altitude.

The maximum permissible exposure (MPE) for each of the laser wavelengths transmitted outside the NASA DC-8 is provided below for a single shot.

Table 2. ANSI standard MPE values for a single pulse

Wavelength (nm)	MPE (J/cm^2)
1064	$5e10^{-6}$
532	$5e10^{-7}$
355	$5.6e^{-3}$
291 & 300	$3e10^{-3}$

*combined energy of two transmitted UV beams.

Eye safety calculations are based on the nominal ocular hazard distance (NOHD) relation developed by the Z-136 Committee on Eye Safety and Tables 1 & 2. Conservatively, the atmospheric transmission is assumed to be T=1.0 for all wavelengths and altitudes. The transmission through the aircraft window reduces the overall output energy by an additional 8% since the window is not coated with anti-reflection dielectrics. No laser beam pulses will overlap on the ground with flight altitudes below 24 kft for the divergences of all the output beams based on the nominal aircraft speeds and the system is eye safe at distances beyond 10 kft. Therefore single pulse calculations are used in the eye safety equation for the range of maximum NOHD for this system for airborne operations.

Eye safety calculations are based on the nominal ocular hazard distance (NOHD) relation developed by the Z-136 Committee on Eye Safety.

The nadir NOHD values for the different wavelengths are given in Table 3, and the NOHD values for the zenith beams are provided in Table 4. Current instrument configurations have the two directions the same. For the UV NOHD calculation, the sum of the two beams is used since the MPE is the same for these two wavelengths and the value is extremely small compared to the other wavelengths. The NOHD is less than 200 ft for the combined UV beams. Note that the UV beams do not transmit through standard BK glass and therefore the NOHD value would be dramatically reduced for hazards within other aircraft. The NOHD for all beams combined (weighted sum) for each direction is less than 10 kft (3 km) and is mainly dictated by the 532nm NOHD.

Table 3. NOHD values for the Nadir transmitted beams

Wavelength (nm)	NOHD (kft)	NOHD (km)
1064	2.87	0.87
532	9.57	2.92
355	0.17	0.05
291 & 300 combined	0.17	0.05

Table 4. NOHD values for the Zenith transmitted beams

Wavelength (nm)	NOHD (kft)	NOHD (km)
1064	2.87	0.87
532	9.57	2.92
355	0.17	0.05
291 & 300 combined	0.17	0.05

9. Ground and Flight Operational Controls & Procedures

Operational controls are available to readily implement the requirements for eye safe operation during ground and flight operations.

1. During all flight and ground tests of the UV lidar instrument onboard the NASA DC-8, operation of the lidar instrument will be controlled by the NASA DC-8 mission manager or his designee. The Mission Manager will maintain direct contact with the Pilot in Charge during flight operations and the Mission Manager will have the final decision on any laser transmission during flight and ground testing.
2. Direct communication between the laser operator and the Mission Manager will be requested for clearance to transmit the laser beams during flights and ground testing. This ensures that all personnel and the FAA have been notified of operations and the communication protocols have been established and that all safety control measures are satisfied.
3. Communication with the Mission Manager will be maintained via use of the headsets for all operations when there is laser transmission outside the laser controlled area described above. This includes ground atmospheric testing and flight operations.
4. During airborne operations, an observer will scan the region around the aircraft to identify any encroaching aircraft. The observer will notify the Mission Manager to terminate any laser operation before aircraft approach the laser beam paths (nadir and zenith directions).
5. TCAS is also used as an additional control measure to ensure approaching aircraft are detected. Monitoring of the TCAS is possible via the onboard data system and the PIC and Mission Manager.
6. Communication with air traffic control will be maintained to provide additional coordination and detection of approaching aircraft and laser transmission will be terminated immediately upon request.

7. The aircraft shutters over the exit and receive windows are controlled by the mission manager and the crew and are open only after a Crew Member has given the all clear during flight to the Mission Manager. The aircraft shutters are closed before the call for seat belts and landing. The laser shall not transmit from the aircraft during take-off and landing.
8. Laser transmission will only be started after clearance from the Mission Manager and Pilot in Charge (PIC) has been granted.
9. The Laser Safety Officer (LSO) shall have the capability to remotely attenuate or block the transmitted beams from the Data Acquisition System (DAS) rack. Moreover, the LSO shall have the capability to shut down the lasers with manual switches located on the lasers and the DAS rack. The mission manager also shall have the capability to terminate power to the DIAL system for final redundancy.
10. The laser divergences are set before each mission and measured to ensure values are correct and consistent with the stated values in the NOHD calculations above.
11. At regular intervals (~1-2 sec) the transmitted beam energies shall be monitored to ensure that they are less than the stated maximum values. Note that values stated as maximum energies are conservative in that the actual values are typical much less. All energies are measured before flight and before initiating transmission outside the aircraft.
12. During flight, an update of the altitude, pitch, and roll angles are recorded and will be monitored in addition to redundant monitoring by Mission Manager’s console.
13. Beams are mechanically steered and are limited in small angles (<3 degrees) due to the beam shields installed on the system.
14. All laser transmission shall be blocked during bank angles of >10 degrees when flying over land and >20 degrees when flying over open water.
15. Laser transmission will be limited by NOHD and altitude AGL (above ground level) and based on wavelengths to ensure that all beams are not hazardous at ground levels.
16. For the visible laser output, the nadir beams will be blocked when flight level is <15 kft AGL. Note that this is less than the NOHD altitude and therefore is a conservative altitude limit.
17. For the IR beams the nadir beams will be blocked when flight level is < 10 kft AGL. Note that this is less than the NOHD altitude and therefore is a conservative altitude limit.
18. For the UV laser outputs can remain on during flight since the NOHD values are less than aircraft separation and they are always eye safe at ground level for all flight altitudes except during take-off and landing.

19. Zenith beams will remain on during all flight altitudes except during take-off and landing except for the requirements provided below during nighttime flights in the Laser Free and Critical Flight Zones near airports (FAA Circular AC70-1).
20. During nighttime operation additional controls are implemented to ensure that the transmitted power density is below the values stated in the ANSI standards for outdoor laser use near airports. The procedures implemented will limit laser transmission within the Critical Flight Zone and the Laser Free Flight Zones.
21. In the Laser Free Flight Zone (ground – 2000 ft AGL and within a 5 nmi radius), the nadir visible lasers will be terminated. The nadir visible beam is less than the required Critical Flight Zone power densities when above 16 kft AGL and will be blocked below this altitude. The zenith beams shall be blocked if flight level is below 10000 ft AGL within the Laser Free and Critical Flight Zones (10 nmi radius).
22. During ground atmospheric testing coordination with the local FAA center will be done in advance and as required by the FAA letter of non-objection.
23. During ground atmospheric testing an observer on the ground will be used to monitor the area for overhead aircraft and give the signal to terminate laser emission to the mission manager if aircraft approach the beam path. The observer is required to be in direct contact with the mission manager to terminate laser transmission during ground tests.
24. During ground atmospheric testing, the mission manager will coordinate with any local airports before transmitting the beam outside of the aircraft.

10. Additional Considerations for laser operations on the NASA DC-8

Organic dyes dissolved in Ethylene Glycol and water serve as the laser gain media in the dye lasers. These dye solutions are periodically changed in the field to maintain peak performance of the dye lasers. The spent dye solutions are stored in a certified waste container and returned to LaRC for proper disposal. Material Safety Data Sheets for the dyes and solvents will be available for the Mission Manager before installation on the aircraft.

Appendix N. Emergency Safety and Evacuation Procedures

DC3 Emergency Safety and Evacuation Procedures during Severe Weather
(draft 23 April 2012)

There are conditions that may occur during the DC3 field campaign that will require close monitoring and potential emergency action to protect life and property in and near the Salina Operations Center. These are severe weather events that may occur in the region and in the vicinity of Salina. The potential for hail, strong straight line winds and even tornados may require quick action by DC3 operations personnel, research facility staff and participants to protect themselves, the aircraft and any ground facilities that may be in the area.

The DC3 operations support team and project forecast/nowcast group will monitor weather conditions during the campaign. Information from the project forecast team and from the National Weather Service will be provided to all concerned and timely updates will be delivered as warranted. It is important to note that the DC3 forecast staff support will not be available 24 hours a day. Typical daily forecast support is from 0700 LST through 1800 LST. This timing may vary depending on aircraft and ground facility support requirements on any given operational day. It will be the responsibility for aircraft project managers or other facility identified personnel to monitor the weather at all other times.

Emergency shelters at the DC3 Operations Center include the stair wells and restrooms in Hangar 600 and a nearby bunker operated by the SAA (Building XXX).

Initial discussions with the DC3 aircraft facilities (NASA DC-8, NCAR GV and DLR Falcon) suggest that the facilities are very interested in the severe weather potential and may choose to evacuate from Salina or return to an alternate airport if they are returning from flight operations. The alternate airports that might be used by the aircraft are listed in Table 3-9. The decision to evacuate to or return to an alternate location is the responsibility of the command pilots and facility project managers.

The National Weather Service (NWS) provides a number of products that are very useful and timely in these hazardous weather situations. The following list describes the products available as well as the valid time frame for the information. The products are listed from the advanced alerts and watches available ahead of a particular event to the most timely and specific alerts and warnings just before and during the severe weather.

Multi-day outlooks (Day 1 to Day 3 and extended to Day 8) Outlooks from the National Severe Storms Forecast Center (NSSFC) are issued each day. Probabilistic to categorical outlooks are provided for the occurrence and location of severe thunderstorms are described. Categories are occurrence of any thunderstorms, and then slight moderate and high probabilities of severe weather.

Tornado Watch (TOA) Conditions are favorable for the development of severe thunderstorms producing tornadoes in and close to the watch area. Watches are usually in effect for several hours, with 6 hours being the most common (also automatically indicates a Severe Thunderstorm Watch).

Tornado Warning (TOR) Tornado is indicated by radar or sighted by storm spotters. The warning will include where the tornado is and what towns will be in its path (also automatically indicates a Severe Thunderstorm Warning).

Severe Thunderstorm Watch (SVA) Conditions are favorable for the development of severe thunderstorms in and close to the watch area. Watches are usually in effect for several hours, with 6 hours being the most common.

Severe Thunderstorm Warning (SVR) Issued when a thunderstorm produces hail 1 inch (27 mm) or larger in diameter and/or winds which equal or exceed 58 mph (93 km/h). Severe thunderstorms can result in the loss of life and/or property. Information in this warning includes: where the storm is, what towns will be affected, and the primary threat associated with the storm. Tornadoes can also and do develop in severe thunderstorms without the issuance of a tornado warning.

Severe Weather Statement (SVS) Issued when the forecaster wants to follow up a warning with important information on the progress of severe weather elements.

NOAA Weather Radio

This over–the-air system allows anyone to hear the latest forecast, watches and warning that are issues for a specific are by the NWS. An inexpensive radio can be purchased that has the specific bands needed to pick up the broadcast anywhere in the US. The system broadcasts local and regional weather information and provides severe weather watches warnings and alerts as necessary. The DC3 Operations Center will have two of these radios operational at all times for participants and be informed about the latest conditions.

Local Media (Radio and TV) The channels and frequencies of local TV and radio stations in the Salina region are on the DC3 web site. They will be monitored as conditions warrant. They use experienced storm chasers during dangerous situations in the region and their information is relayed to the public as soon as possible.

The DC3 operations support staff and forecast team will issues weather updates and alerts as conditions warrant. The final decision to move the aircraft from Salina rests with the facility managers.

Aircraft Evacuation Decision Thresholds

(to be completed by RAF GV Operations)

(to be completed by DC-8 Operations)

(to be completed by DLR Falcon Operations)