NCAR Research Aviation Facility

Bulletin No. 7

FLIGHT PLANNING:
THE NSF/NCAR L-188C ELECTRA

Note: The NSF/NCAR L-188C ELECTRA has been retired from service as of January 1, 2001.
The information contained here is for historical purposes.

The purpose of this Bulletin is to acquaint prospective users with the most important considerations in developing research flight plans. The NCAR pilots, of course, are responsible for the detailed planning of specific flight profiles, but for the user to complete the flight operations section of the Request for Aviation Support Form (See *Research Aviation Facility Bulletin No. 1*.), a basic understanding of the aircraft's performance is essential. An overview and summary of capabilities of the Electra is described in *Research Aviation Facility Bulletin No. 4*.

Figure 1--The NSF/NCAR Electra

Specifications and Performance

The Lockheed Electra (Figure 1) is a pressurized, low-wing, turbo-propeller airplane, which was designed as a medium-range airliner. It is powered by four Allison 501-D13 constant-speed, axial-flow, turbine engines that drive four-bladed, full-feathering, reversible-pitch, turbo-propellers. Flight is approved in known icing conditions; however, external instrumentation installations may restrict operations in icing conditions.

Table 1 summarizes the basic performance characteristics of NSF/NCAR's Lockheed L-188C Electra aircraft. The information is based on years of operational experience with this aircraft in a research configuration. It reflects a 10% reduction in performance from manufacturer's specifications caused by numerous externally mounted sensors, pods, etc.

Table 2 has some examples of expected maximum flight times.

The following considerations were used in constructing Tables 1 and 2:

1. **Standard day**: The standard day is defined as sea level, zero wind with a temperature of 15C and is used here to specify typical runway length and gross weight requirements. The NSF/NCAR Electra is operated in accordance with the balanced field concept. This means that the airplane must have enough runway to accelerate to a specified speed (known as the critical engine failure speed), have an engine failure at that point, and either continue to takeoff successfully or stop on the remaining length of the runway. Furthermore, a minimum rate of climb on three engines must be assured.

   There are numerous factors to be considered in determining the distance needed for takeoff or landing. The most significant of these are air temperature, pressure altitude and the gross weight of the airplane. The following examples illustrate the large increases in runway length required by changes in these factors.

   The runway required for a fully loaded Electra (116,000 lb) at sea level with zero wind and a temperature of 15C is 5,200 ft. At the same temperature, the Electra would require 9,750 ft of runway and would be weight-limited to 105,000 lb when taking off from an airport elevation of 6,000 ft. Significant increases in temperature result in a substantial reduction in performance. At -7C, a fully loaded Electra taking off from a sea level base would require 4,550 ft for a runway. At 32C, all other conditions remaining the same, 7,500 ft of runway would be required. Each of the above examples assumes a dry runway. Takeoff weight may also be limited because of the requirement to maintain a specified climb rate after takeoff.

   A combination of high airport elevation and high temperature results in a dramatic decline in an aircraft's takeoff performance. Normally, the only variable over which we have control is the gross weight of the airplane. Assuming that each crew member and all research equipment are essential to the mission, we are faced with reducing fuel load when a lower gross weight is necessary to comply with the balanced runway requirement. The result, of course, is a reduction in range and/or the endurance of the aircraft.

2. **Maximum gross weight**: Sometimes referred to as the "all-up gross weight," this is the maximum allowable weight of the aircraft, crew, passengers, fuel, and equipment.

3. **Payload**: Difference between the empty weight and the maximum zero-fuel weight. Crew and baggage are included in this figure.

4. **Maximum zero-fuel weight**: This is the maximum allowable weight of the aircraft plus complete payload, including all crew members, baggage, spare parts, etc. Fuel is not included in this figure. Any weight added beyond the maximum zero fuel weight must be fuel.

5. **Maximum landing weight**: The maximum weight at which a normal landing can be made. Any landing executed when the aircraft weight exceeds this figure would be an emergency situation.

6. **Visual flight rules (VFR)**: VFR is briefly defined as a flight out of clouds and below 18,000 ft above mean sea level. A minimum of 45 minutes of reserve fuel is required to allow for diversions to alternate landing fields, should the primary destination airport be closed. Additional reserve fuel may be necessary depending on the distance to a suitable alternate.

7. **Instrument flight rules (IFR)**: All flights at flight level 180 and above, along with flight in clouds and in terminal control areas, must be conducted under instrument flight rules. This means that all phases of the flight must be conducted under the control of the appropriate air traffic control facility. The aircraft must have fuel to fly to the destination airport and then to a designated alternate airport, plus 45 minutes of reserve fuel.

8. **Cruising range**: The following example will illustrate how Table 1 can be used to calculate a rough estimate of the cruising range of the aircraft. Taking off from sea level with full fuel (43,684 lb) and climbing to 15,000 ft, 1,400 lb of fuel are used, and 50 nmi are flown in the 13 minutes required to climb. Considering 11,300 lb of fuel are required for standard operating reserve and IFR reserve fuel, 32,384 lb of fuel are available for research (43,684 lb - 11,300 lb -1,400 lb = 30,984 lb). At 15,000 ft and a research speed of 220 KIAS (274 KTAS) is obtained with an average fuel flow of 4,171 lb/hr. With 30,984 lb of fuel available for research, 7.4 hours of research can be flown. At a true airspeed of 274 kt, 2,035 nmi of research can be flown (30,984 lb @ 4,171 lb/hr = 7.4 hours x 274 kt = 2,035 nmi). The 2,035 nmi of research, plus 50 nmi flown in the climb equals 2,085 nmi total range.

   It should be noted that reserve fuel requirements may be considerably higher in areas with no suitable landing alternates. The results would be less fuel available for research and, therefore, less total range. In addition, descents and climbs for atmospheric soundings consume more fuel than cruising, and total range will be reduced. The values are charted values for a standard atmosphere and a standard aircraft and do not take into consideration parasitic drag of the aircraft, which will reduce performance.

9. **Observer positions**: The number of observer/equipment operator stations available is normally 12 for ferry flights and 14 for research flights.

Altitude Assignment Procedures

Flights operating under VFR (Visual Flight Rules) are expected to conform to the following:

- Eastbound (magnetic course between 0 and 179 degrees) : altitude should be odd thousand MSL (above mean sea level) plus 500 feet.
- Westbound (magnetic course between 180 and 359 degrees) : altitude should be even thousand MSL plus 500 feet.

Flights operating under IFR will normally be assigned altitudes as follows:

- Eastbound: odd thousands of feet.
- Westbound: even thousands of feet.
- Starting at 18,000 ft, all operations must be under IFR (Instrument Flight Rules). Altitudes of 18,000 ft and above are referred to as Flight Levels (FL) with all aircraft using a standard altimeter

setting of 29.92 inches of mercury. The east-odd, west-even concept applies up to FL290 (29,000 ft).

- At FL290, all altitude assignments are odd thousand feet, with FL290 being eastbound, FL310 westbound, etc.
- Above FL600 airspace is uncontrolled. However, other traffic rarely will be found above FL410. Consequently flights at FL410 and above should be relatively free of ATC (Air Traffic Control) constraints.

While the above may sound somewhat restrictive, the air traffic control system is normally very accommodating in supporting research flights when the mission requirements are in conflict with the normal altitude assignment procedures. If vertical maneuvering is necessary, a block of altitudes can usually be obtained. However, it should be pointed out that the more a flight plan conflicts with normal procedures, the more one is likely to encounter delays, and in some cases refusal, to get the requested air space. Advance planning and involvement of RAF will help to minimize these problems.

Communications

All NSF/NCAR aircraft are equipped with dual very high frequency (VHF) communication radios channeled for the air traffic control 720 channel band of 118.00 to 135.975 MHz. Normally these radios are required by the flight crew during routine traffic control communications. There are times, however, during VFR flight in low-density areas, when one VHF radio can be used for scientific purposed by observer crew members from the cabin. For aircraft to ship to aircraft (maritime) communications, the VHF-FM channels can be used. These channels include No. 16 (156.8 MHz), No. 06 (156.3 MHz), No. 68 (156.425 MHz), No. 09 (156.45 MHz), No. 70 (156.525 MHz), and No. 72 (156.625 MHz).

High frequency (HF) radios are installed on the Electra that can achieve global communications but are generally not intended for use in routine, air-to-ground scientific communications. HF radio equipment is used when the aircraft is operating out of VHF range and under ideal conditions. It has a range of up to 12,000 nmi. As ideal conditions are not always present, the quality of reception and range of this equipment are at times erratic.

Note: The use of frequencies for scientific purposes (i.e., other than routine contact with FAA) requires NCAR to apply for authorization in advance of a project. It is important that needs for radio communications are clearly defined in the flight request.

Persons inexperienced in radio communication frequently fly on NSF/NCAR aircraft as observers and have a requirement to communicate with ground stations, ships or other aircraft. It is deemed appropriate, therefore, to discuss several techniques that will improve overall communications quality. These are:

1. Think before keying your transmitter. Know what you are going to say. Be brief.
2. Listen before you transmit. Keying your transmitter while someone else is talking will be futile and will probably jam their receiver, causing a repeat call.
3. The microphone should be held close to your lips. After pressing the mike button, a slight pause (one second) may be necessary to be sure the first word is transmitted.
4. Speak in a normal conversational tone. With higher noise levels in the aircraft, the "normal" voice level tends to increase; thus, it may be appropriate to lower your voice volume for better transmission.

A Research Intercommunication System (ICS) is available for use by the project participants during research operations. During the preparation phase, an RAF Project Manager will inform and familiarize the requestor with the ICS to ensure that this system is used to its full potential.

Crew Rest and Flight Duty Limits

Adequate rest for crew members is essential for the safe and efficient operations of NSF/NCAR aircraft in support of research programs. The restrictions in this section are the minima and maxima allowable. The 14-hour duty limit is intended for short, intensive operational periods and is not to be considered as a normal work day for NCAR flight crews. Investigators must be aware of other factors that flight crews must contend with, such as the fatiguing effects of continued IFR operation, extremes of temperature, complexity of mission requirements, and other variables that the pilot-in-command must consider in determining actual crew limits for any operation. During extensive research periods, proper rest becomes increasingly important, and when deemed necessary, the project pilot may elect to declare additional crew rest periods other than those listed below.

Single Electra crew duty limits, assuming ideal working conditions		
1.	Any 24-hour period	9 flight hrs
2.	Any consecutive 7 days	35 flight hrs
3.	Any 30-day period	110 flight hrs
4.	Consecutive working days	6 days
5.	Crew duty period	14 hrs
6.	Minimum crew rest period	12 hrs

Flight hours are defined as that time from the moment the aircraft first moves under its own power for the purpose of flight until the moment it comes to rest at the next point of landing ("block-to-block time").

The crew duty period starts at the briefing time, or when the crew starts being "on alert," and ends when the aircraft is shut down and secured. Days off will be scheduled at least 12 hours in advance, with the crew being relieved of all duties.

Due to insurance liability considerations, the crew must be limited to the necessary project participants. The maximum number of people on a given mission is 19.

Further Information

Investigators interested in discussing any use of the NSF/NCAR aircraft or its instrumentation, including questions on scheduling, may contact the Facility Liaison for Project Support at (303)497-1047. Questions concerning flight operations could be addressed to the Chief Pilot, phone: (303)497-1057.

Table 1 PERFORMANCE SPECIFICATIONS (STANDARD DAY) Lockheed Model L-188C Electra Registration Number N308D	
Category	**Weight**
Maximum gross weight for takeoff	116,000 lb
Maximum gross weight for landing	95,650 lb
Maximum zero fuel weight	86,000 lb
Empty weight (no crew, no fuel, empty cabin)	66,724 lb
Fuel capacity	6,520 gallons (43,684 lb)
Payload (crew and all equipment)	19,276 lb
Typical Runway Length Requirements	
Sea Level - ISA - 116,000 lb gross wt	5,200 ft
5,000 ft elevation - ISA - 116,000 lb gross wt	8,300 ft
Cruise Speeds	
Maximum distance	300 kt TAS (True Airspeed)
Research (typical)	200-220 kt IAS (Indicated Airspeed)
Slow flight	150 kt IAS
Fuel Flow Average at Research Speed (220 kt Indicated Airspeed)	
@ 1,000 ft MSL, 224 kt TAS (True Airspeed)	4,772 lb/hr
@ 5,000 ft MSL, 237 kt TAS	4,562 lb/hr
@ 10,000 ft MSL, 255 kt TAS	4,317 lb/hr
@ 15,000 ft MSL, 274 kt TAS	4,171 lb/hr
@ 22,000 ft MSL, 308 kt TAS	4,028 lb/hr

Maximum Range (With IFR Reserve and Full Fuel--No Wind)		
Altitude	**Total Distance (nmi)**	**Total Flight Time (hr)**
< 1,000 ft	1,440	7.2
5,000 ft	1,617	7.7
10,000 ft	1,864	8.1
15,000 ft	2,097	8.2
20,000 ft	2,386	8.6
25,000 ft	2,686	8.8

Climbing Performance			
To	**Time**	**Fuel**	**Distance to Climb (From Sea Level)**
5,000 ft	4 min	400 lb	12 nmi
10,000 ft	8 min	800 lb	28 nmi
15,000 ft	13 min	1,400 lb	50 nmi
20,000 ft	22 min	2,100 lb	90 nmi

Aircraft Altitude (Operating)	**Cabin Altitude**
28,000 ft (Maximum)	8,000 ft
22,000 ft	4,900 ft
15,000 ft	Sea Level
Maximum Endurance (With IFR Reserve) @ Optimum Altitude	8.5 hr

Observer Stations Available	
Ferry flights	12
Research flights	14

Table 2 FLIGHT PLANNING ESTIMATES Lockheed Model L-188 Electra Registration Number N308D		
Assumptions:	Full fuel at takeoff	
	Transit to and from operating area at high altitude (> 18,000 ft)	
	IFR fuel reserves	
Distance from Base (nmi)	**Research Duration at Low Altitude (hr)**	**Total Flight Time (hours)**
940	1.0	8.2
700	2.5	7.9
500	3.5	7.7
300	4.5	7.6
150	6.0	7.5

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Last update: Wed Oct 24 14:06:56 MDT 2001