The Chesapeake Lighthouse and Aircraft Measurements for Satellites Experiment

CLAMS

Flight Test Operations & Safety Report

Prepared for the Operational Safety Review

5-30-2001

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FLIGHT TEST OPERATIONS AND SAFETY REPORT

1. Program Overview

1.1 Program Objectives and General Description.

NASA has developed an Earth Observing System (EOS) consisting of a series of satellites designed to study global change from space. The EOS flagship is the EOS TERRA satellite, launched in December 1999, equipped with five unique sensors to monitor and study the Earth s heat budget and many of the key controlling variables governing the Earth s climate system. **CLAMS is the Chesapeake Lighthouse and Aircraft Measurements for Satellites field campaign designed to validate and improve EOS TERRA satellite data products being derived from three sensors: CERES (Clouds and Earth s Radiant Energy System), MISR (Multi-angle Imaging Spectro-Radiometer) and MODIS (MODerate Resolution Imaging Spectroradiometer).** CLAMS is jointly sponsored by the CERES, MISR and MODIS instrument teams and the Global Aerosol Climatology Project (GACP). CLAMS primary objectives are to validate satellite-based retrievals of aerosol properties and vertical profiles of radiative flux, temperature and water vapor. Central to CLAMS measurement strategy is the Chesapeake Lighthouse, a stable sea platform located in the Atlantic Ocean, 13 miles east of Virginia Beach near the mouth of the Chesapeake Bay and the site of an ongoing CERES Ocean Validation Experiment (COVE). CLAMS will deploy six research aircraft to make detailed measurements of the atmosphere and ocean surface in the vicinity of COVE, over the surrounding ocean and over nearby surface sites. These measurements will be made coincident with the noon EOS TERRA satellite overpass of COVE. Additionally, a portion of one mission will coincide with a NOAA-16 overpass. Tables 1(a) and (b) list the key satellite overpass dates and times.

1.2 Program Management

CLAMS is being managed at NASA LaRC. Table 2a lists CLAMS primary management personnel and affiliations. A mission operations center will be established at Wallops Flight Facility where all aspects of CLAMS mission operations will be coordinated and controlled by the Lead Mission Scientist with CLAMS management personnel and key mission scientists representing the co-located aircraft platforms and aircraft instrumentation (Table 2b).

1.3 Selected Aircraft.

Six research aircraft have been selected to participate in CLAMS, the NASA ER-2, the NASA OV-10, the University of Washington Convair 580 (CV-580), the Proteus, a Cessna 210 and a Lear 25C. It is noted here that some of the aircraft have scientific objectives for other programs and at times will operate outside the range of authority of CLAMS management. Table 3 provides more details regarding CLAMS participating aircraft including aircraft certification information.

1.3.1 ER-2

The NASA ER-2 serves as a surrogate satellite, flying at 65,000 feet with NASA airborne counterparts to two of the key EOS TERRA instruments but taking data at much higher horizontal resolution and at times when the satellite is unavailable. The ER-2 will also map the vertical distribution of temperature, water vapor and aerosols over a wide area. NASA Dryden is responsible for the operational safety review of the ER-2

1.3.2 CV-580

The University of Washington Convair 580 (UW CV-580) will make in-situ measurements of atmospheric aerosol properties between the surface and 25,000 feet, characterize total column spectral aerosol optical thickness and measure the solar reflectance properties of the ocean surface, all key elements to validating and improving the satellite retrieval methodologies. NASA Wallops is responsible for the operational safety review of the CV-580. A NASA AMES scientist will fly aboard the CV-580 on some flights. Several NASA instruments are included in the CV-580 payload.

1.3.3 OV-10

The NASA LaRC OV-10 will map the spectral solar and broadband radiative properties of the ocean surface and in the boundary layer below 10000 feet to study scene variability and determine platform effects at COVE. NASA LaRC is responsible for the operational safety review of the OV-10 and it s payload will include NASA equipment and personnel. The OV-10 conducts research operations under the Flight Safety Release for the CERES Fixed-wing Radiometer (CFAR) System reissued by the NASA LaRC ASRB on April 11, 2001 which is valid until March 13, 2002.

1.3.4 Cessna 210

A Cessna 210, owned and operated by I.K. Curtis Services, Inc. in Burbank, CA., will fly the SpecTIR Corporation s Research Scanning Polarimeter at 12,000 feet for aerosols and occasionally at 300 feet to measure radiative characteristics of the ocean surface. This instrument is proposed for a future EOS satellite platform and represents a collaboration with scientists from Columbia University and NASA GISS. No NASA instrumentation or personnel will be aboard the Cessna 210 during CLAMS flights. The Cessna 210 will be inspected by the ASO at Wallops Flight Facility upon arrival and before CLAMS mission operations commence.

1.3.5 Proteus

The Proteus, owned by Scaled Composites, LLC. in Mojave, CA., will fly NASA s scanning fourier transform spectrometer (NAST-I), NASA s FIRSC instrument and the Massachusetts Institute of Technology microwave radiometer (NAST-M) to measure the vertical distribution of temperature and water vapor and to test new aerosol retrieval methodologies being developed for infrared wavelenghths. An operational safety review of the Proteus was recently conducted by NASA LaRC for the TRACE-P experiment. No significant modifications are being made to Proteus for CLAMS. No NASA personnel will fly on the Proteus.

1.3.6 Lear Jet

A Lear 25C, owned and operated by Flight International, Inc., Newport News, VA., will test NASA LaRC s new oxygen A-band spectrometer (LAABS) for retrieving aerosol properties, flying at 40,000 feet. A NASA LaRC scientist or engineer may fly on the LEAR during CLAMS missions. NASA LaRC is responsible for the operational safety review of the Lear 25C.

1.4 Proposed Aircraft Modifications and Design Criteria.

All aircraft modifications were conducted via the home organizations certification process described in table 3. The Lear 25C has been previously modified and approved to fly nadir-viewing instrumentation by the NASA LaRC ASRB on March 3, 1999. The only required modification for CLAMS is the addition of a LAABS instrument/aircraft mounting interface and mounting of the flight electronics into a Lear specific 19-inch electronics rack. These modification are made inside the aircraft cabin and will be FAA DER approved.

1.5 Instrumentation Hardware/Software and Flight Test Data Measurement Requirements.

Tables 4 and 5 list the aircraft and surface based instrumentation, primary measurement variables and associated science personnel. The vicinity of the Chesapeake Lighthouse (COVE) will be one of the primary target areas for aircraft operations. A zenith pointing Micropulse Lidar (MPL) will be operating under permit at COVE for the duration of CLAMS. The MPL is designed to be eye safe and has been reviewed and approved by the RSO and Non-Ionizing Radiation Committee at NASA LaRC. Operation of the MPL at COVE requires mandatory notification be given to Langley Air Force Base Operations, the FAA Norfolk Approach Control and Leesburg Flight Service Station. The COVE Site Scientist will provide the appropriate notifications prior to and after MPL operations. Weather Balloons will be launched from the COVE platform prior to and following aircraft operations.

1.6 Contractual Requirements.

Contractual agreements have been made with the owners of the non-NASA aircraft listed in section 1.3.

1.7 Involved Agencies.

Analytical Services and Materials, Inc. (AS&M)

Columbia University

Flight International

Joint Center for Earth Systems Technology (JCET)

McMillen Enterprises, Inc.

NASA Jet Propulsion Laboratory (JPL)

NASA AMES Research Center (ARC)

NASA Goddard Institute for Space Studies (GISS)

NASA Goddard Space Flight Center (GSFC)

NASA Langley Research Center (LaRC)

Old Dominion University (ODU)

Science Applications International Corporation (SAIC)

Scaled Composites, LLC.

Science Systems and Applications, Inc. (SSAI)

University of Maryland-Baltimore Campus (UMBC)

University of Washington (U. of Wash.)

University of Wisconsin (UW)

Wallops Flight Facility (WFF)

1.8 Summary of Supporting Research and Tests.

1.8.1 Analytical

N.A

1.8.2 Wind Tunnel

N.A

1.8.3 Simulation

N.A

1.8.4 Ground Operations Systems Checkout

Complete systems checkouts will be performed before the start of flight experiments.

1.9 Proposed Schedule Milestones.

CLAMS mission scheduled for science flights July 10 — August 2, 2001.

2. Flight Test Operations.

2.1 Location

The CLAMS Mission is scheduled to be conducted off the North Carolina, Virginia, and Maryland Capes, principally centered near the Chesapeake Light Platform, NOAA CHLV2, (COVE) (See Figure 1). The CV-580, Lear 25C and Proteus will operate within 200 nmi from shore, the OV-10 within 55 nmi from shore and the Cessna 210 within 25 nmi from shore. The primary targets are the Chesapeake Lighthouse and several offshore NOAA buoy s. Use of the Virginia Capes (VACAPES) warning area airspace will be coordinated as appropriate. Research flights will be conducted using the general flight-profile types defined in the Flight Profiles Section 2.5.1. CLAMS management personnel and mission scientists will coordinate and conduct the mission operations at WFF, the site of CLAMS field office and operations center. Four of the six research aircraft (ER-2, Proteus, CV-580 and Cessna 210) will operate primarily from WFF. The LaRC OV-10 will operate primarily out of NASA LaRC and the Lear 25C out of Patrick Henry Field in Newport News or Langley Field. The OV-10 s current Flight Safety Release (FSR) allows operation out to 50 nmi from shore. CLAMS will require a 5 nmi extension to this limit to encompass an offshore buoy located exactly 50 nmi from shore over which the OV-10 will conduct some flight operations.

2.2 Planned Start of Flight Tests

Test flights are scheduled to begin on July 10, 2001 and continue as weather conditions permit throughout the three week mission period ending August 2, 2001. Check flights for the various aircraft will be conducted prior to July 10.

2.3 Planned Number of Flights

The six participating CLAMS aircraft will fly a minimum of one sortie per mission-day, with additional daily flights planned for several aircraft to conduct small-scale profiles over near base targets. Table 6 includes the flight hour budgets and typical mission duration for each aircraft during CLAMS.

2.4 Frequency of Flights

Selection of desired flight days is typically based upon weather and satellite overpass timing, with the majority of test flights requiring near clear- sky weather conditions. Cloud climatological data would indicate that five to ten flight days are possible during the mission period.

2.5 Test Procedures

2.5.1 Flight Profiles

A-B Leg Profile (All Aircraft): Single-leg track flown point-to-point at a fixed flight level for durations of 10 to 30 minutes. Distances depend on aircraft speed, available airspace and may be shortened by flying reverse heading racetrack patterns. Altitudes may vary from 100 ft to 65,000 feet above sea level (ASL). Selected flight level is dependent upon the aircraft and daily mission science objectives.

BRDF Profile(CV-580): Circular pattern, centered about a fixed waypoint and flown at a bank angle of 20 degrees. Pattern may range in diameter from several nautical miles (nm) up to 10 nm, dependent upon science objective. Altitudes range from 300 ft ASL to 25,000 ft ASL.

Spiral Profile (CV-580, Proteus): Ascending and descending spiral profiles are flown at spiraling rates from 200 ft/min to several thousand ft/min, dependent upon science objectives and local aerosol concentration levels. Altitudes range from 100 ft ASL to 55,000 ft ASL. Selected profile diameter for each mission may range from several nautical miles up to 40 nm. It is a circular pattern, centered about a fixed waypoint and typically flown at bank angles of less than 10 degrees.

Crop-Duster Box Profile (All Aircraft): Profile consists of multiple parallel flight-legs, equally spaced to provide blanket coverage of desired target area. All flight legs are flown at the same flight level. Flight levels may vary from 100 ft. ASL to 65,000 ft ASL. Box sizes may vary from several nm to several hundred nm.

Descending Step Profile (CV-580): Profile is a series of constant altitude straight leg or racetrack patterns descending in altitude. Flight levels depend on predetermined vertical aerosol structure.

2.5.2 Flight Procedures

In this section, attention is given to the few scenarios that require any of the CLAMS aircraft to operate in close proximity to each other. The ER-2 will always operate above 60 kft. No other CLAMS aircraft will operate anywhere near the ER-2. The Proteus will generally operate at 55 kft. At times the Proteus will fly ascending and descending spirals from 1 kft to 55 kft with variable climb rates (~400 -1000 fpm) and horizontal pattern ranges from 25 to 45 nmi. The only requirement for coincident aircraft data during a Proteus spiral is for the ER-2 to be overhead at 65kft. Therefore,

all Proteus profiles will be conducted in areas clear of all other CLAMS aircraft operations. The Lear 25C will always operate at 40 kft. No other CLAMS aircraft will penetrate the Lear s altitude space. The Cessna 210 will operate primarily at 12 kft. Occasionally, the Cessna will make measurements from 300 ft but only when no other aircraft are operating below 2000 feet or in an area offset at least 10 nmi horizontally from any other CLAMS aircraft patterns. If Proteus profiles are required at the same time the Lear or Cessna are operating, the Proteus profiles will be conducted at least 10nmi from either aircraft s operating area. The OV-10 will conduct most of it s flight missions at 300 ft in the vicinity of COVE. On occasion it will fly short transects near COVE at 100 ft and may fly 15 minute constant altitude flight legs between 1 kft

and 10 kft. CLAMS will require that the OV-10 occasionally operate in close proximity to the CV-580 as discussed below. The CV-580 will operate between 100 ft and 25 kft. Most of it s flight hours will be dedicated to profiling between 300ft and 10kft. On occasion, depending on the atmospheric aerosol structure depicted by the COVE MPL, the CV-580 may profile above 10kft to as high as 25 kft. On those occasions, the Cessna 210, at 12 kft, will be required to egress the profiling area by at least 5 nmi until the CV-580 has returned to an altitude at or below 10kft. The OV-

10 will only operate in the CV-580 profiling area below 1000 feet and will be required to egress the profiling area by at least 5 nmi before the CV-580 is allowed to profile below 2000 ft. The CV-580 will also fly constant altitude BRDF patterns between 300 ft and 25 kft. CLAMS will require that the CV-580 execute this pattern at 800 ft while the OV-10 executes it s 300 ft crop-duster directly below. All aircraft operations during the CV-580 BRDF s will be separated by at least 500 ft vertically or 10nmi horizontally. The CV-580 will also be required to fly 300 ft transects for durations of 15 minutes to 1 hour. The only CLAMS aircraft that could be below 1000 ft near the time of these transects is the OV-10. In those cases the OV-10 will be required to egress the area by at least 5 nmi. On several occasions during CLAMS, the OV-10 and CV-580 will fly in formation for 5 to 10 minutes while the CV-580 is at 300 ft. This will be done in one of two ways. The first involves the OV-10 flying at 400 ft and following at least 5 nmi behind the CV-580. Figure X illustrates this scenario. The second scenario would involve the two aircraft flying side-by-side at 300 ft separated horizontally by 300 feet. Since the CV-580 flies about 40 kias faster than the OV-10, the CV-580 would lag the OV-10 for the first half of this pattern and overtake the OV-10 at the midpoint.

2.6 Planned Flight Test Envelope.

None of the proposed flight test profiles and flight envelopes approach or exceed the normal operating envelope of any of the participating aircraft and do not exceed any limits defined in the Operators Handbook for each aircraft involved or within any restrictions which may be in effect. The OV-10 s current FSR allows for operation down to 100 ft MSL for brief periods of time. During CLAMS, the OV-10 will need to operate between 100 ft and

500 ft MSL for extended periods of time to accomplish the flight profiles detailed in section 2.5.

3. Support Requirements.

3.1 Support Organizations and Their Responsibilities.

N.A.

3.2 Transportation to Test Location.

N.A.

3.3 Chase.

N.A.

3.4 Photo and/or TV Coverage.

N.A.

3.5 Tracking.

N.A.

3.6 Telemetry.

N.A.

3.7 Communications.

Specific Frequency Assignments will be identified and assigned at the CLAMS Daily Mission Briefings as required. For Frequency Information, (see Table 7) CLAMS Flight Operations Communications Frequencies . As discussed in section 2.5, there will be a few occasions that several aircraft may operate in close proximity to each other. These aircraft will maintain aircraft-to-aircraft communications with each other for conflict avoidance. Additionally, a call-back capability will be maintained. For low altitude operations over water, a higher flying CLAMS aircraft will maintain communications for relay of emergency information to shore. Briefings will be conducted daily prior to each mission, where pre-mission plans, weather, communications, participants, and locations will be addressed in detail. Post briefings are also expected to address lessons learned and suggestions for improvements, deletions or additions to be applied to the future pre-flight planning sessions. Daily communications with the COVE site scientist and mission personnel associated with the two aircraft not operating from WFF are required. A telecommunications link is established between CLAMS WFF mission operations center and a local operations center at NASA LaRC to facilitate full participation in mission planning and briefing activities.

3.8 Meteorological.

CLAMS requirements for weather briefings and weather data will be provided through the establishment of a mission weather office with satellite downlinks and real-time weather radar imagery augmented by existing WFF daily weather briefings.

3.9 Data.

N.A.

3.10 Other Special Support Requirements.

N.A.

4 Safety

4.1 System Safety Program.

The general techniques used to establish and maintain system safety are to:

- Ensure that a flight readiness review is conducted as appropriate for each aircraft covering airworthiness and research system operations.
- Conduct daily mission planning and briefing sessions from a mission operations center established at Wallops Flight Facility
- Conduct detailed flight profile planning to minimize the potential for aircraft conflict
- Ensure that appropriate communications and navigation systems are used on each aircraft
- Utilize air-to-air communications and normal see-and-avoid procedures for further conflict avoidance

4.1.1 Hazards Analyses

See Attached Appendix

4.1.2 Risk Assessments

See Attached Appendix

4.2 General Operational Restrictions and Conditions

4.2.1 Weather

CLAMS Mission Weather requirements are for virtually clear sky days and normal surface winds. Surface winds only restrict the take-off and landing capability of the participating aircraft and is addressed on a case by case basis. The several scenarios involving multiple aircraft (ref. sec. 2.5) will be conducted under VFR weather minimums.

4.2.2 Personal Equipment.

Each Participating Aircraft shall have Personal Floatation Equipment on-board for each person.

4.2.3 Minimum On-board Equipment (Go, No-Go Checklist).

Each Participating Aircraft Pilot is responsible for maintaining a Checklist of their operational requirements. The CLAMS Mission Manager is the Final Authority on all Go/No-Go decisions related to the overall mission.

4.2.4 Weight and Balance.

N.A.

4.2.5 Flight Test Envelope (V-n).

All aircraft will operate within their normal operational envelope.

4.3 Abort Procedures.

An emergency exit plan with specific procedures for each aircraft will be briefed before each mission.

4.4 Emergency Plans and Procedures.

Prior to CLAMS first mission, a detailed briefing will be conducted detailing abort procedures and emergency plans. A call-back capability will be maintained. For low altitude operations over water, a higher flying CLAMS aircraft will maintain communications for relay of emergency information to shore.

Radio communication will be established between the mission operations center and all participating aircraft either directly or via radio relay through CLAMS high altitude aircraft and/or the NASA LaRC flight control center.

4.5 Configuration Control Responsibilities.

The CLAMS lead mission scientist has overall responsibilit configuration control.

4.6 Other