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REMOTE SENSING AIRCRAFT PLAY A VITAL ROLE

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Introduction

The Emergencies Science Division (ESD) of Environment Canada owns and operates two aircraft out of the MacDonald-Cartier International Airport in Ottawa, Ontario. The aircraft operate as platforms for developing and testing state-of-the-art sensors and are also called upon to respond to environmental emergencies.

Under a commercial operating certificate, the aircraft conduct remote sensing missions on a cost-recovery basis for government agencies and commercial organizations around the world and are available to do more of the same in the future.

The two aircraft, one a DC-3 and the other a Convair-580, are uniquely equipped with leading edge sensors and are designed so that new sensors can be incorporated if required. The DC-3 is presently equipped for responding to oil spill emergencies.

The DC-3 houses a state-of-the-art scanning laser fluorosensor, infrared and ultraviolet cameras, and two down-looking video cameras operating in the visible region of the electromagnetic spectrum. The DC-3 can also house a variety of other sensors and has done so on many occasions.

The Convair-580 houses two world-class Synthetic Aperture Radars (SARs) with interferometric and polarimetric imaging capabilities. These radars have collected data around the world in support of a variety of multi-agency and multinational programs.

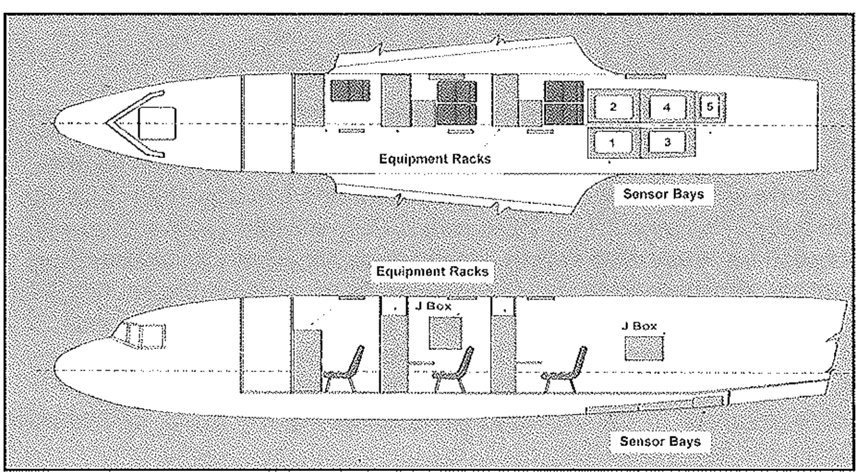
This article looks at the role played by two aircraft in the remote sensing activities of Environment Canada's Emergencies Science Division. The aircraft - a DC-3 and a Convair-580 - serve in many capacities, including acting as airborne platforms for developing and testing new sensors, responding to oil spill emergencies, and collecting remotely sensed data for government agencies and commercial organizations. The aircraft fly in many locations around the world to collect various types of data. Both aircraft were involved in the investigations following the crash of Swissair flight 111 last year.

The DC-3 owned by the Emergencies Science Division was manufactured by the Douglas Aircraft Company as a C-47, the military version of the DC-3. It was converted to a civilian version and has been used as a remote sensing platform for almost 30 years.

The DC-3 - A Venerable Aircraft

The DC-3 owned by the Emergencies Science Division is a venerable aircraft that has been operating as a remote sensing platform for nearly three decades. It was manufactured by the Douglas Aircraft Company in Long Beach, California as a C-47 military version of the DC-3 and was completed on February 19, 1944. The aircraft was converted to a civilian version in 1963 and is now registered as a model DC3C-S1C3G (s/n 12295).

The DC-3 is equipped with four large sensor bays (99 x 78 cm) and one small sensor bay (50 x 78 cm). Three dual equipment racks (standard 48-cm width) are installed on the starboard side of the aircraft. The aircraft is equipped with two 300-amp DC generators and 80% of this power is available for sensor installations. Electrical power is available in the form of 28 volts DC, 60 Hz, and 400 Hz AC.



This diagram shows the sensor bays, equipment racks, and the operator's seats as installed inside the DC-3. The three 48-cm dual equipment racks are situated on the starboard side of the aircraft.

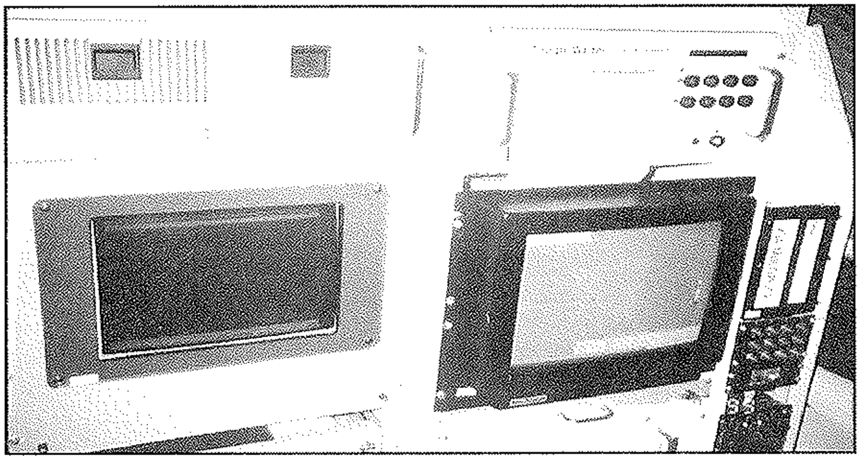
SLEAF

Most of the time, the DC-3 is equipped to respond to oil spill emergencies and can do so in a matter of hours. In this capacity, the DC-3 houses state-of-the-art equipment including one of two laser fluorosensors. The current generation of laser fluorosensor is known as the SLEAF (Scanning Laser Environmental Airborne Fluorosensor).

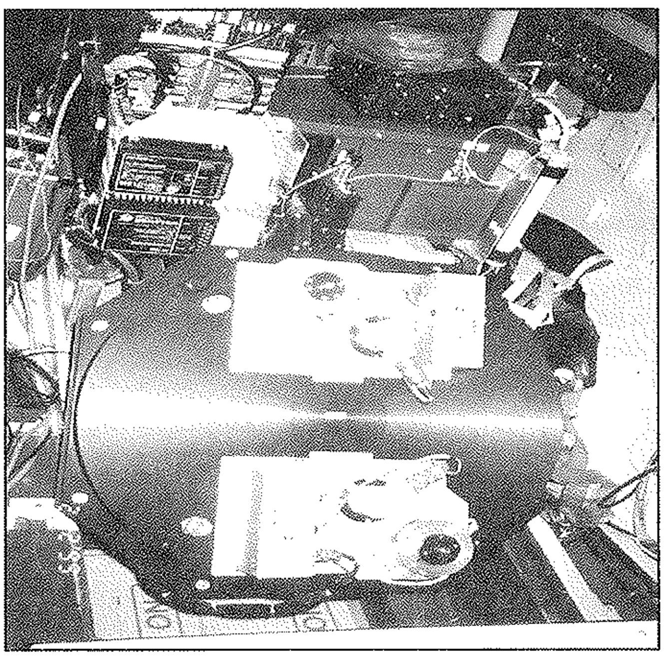
The SLEAF is designed to detect and map oil and related petroleum products in a variety of marine and coastal environments. The SLEAF sends an ultraviolet laser beam down to the surface and induces fluorescence in substances such as oil that contain polyaromatic hydrocarbons (PAHs). Two scanner heads provide the wide/narrow cross-track coverage required for investigating oiled shorelines.

The fluorescence is captured through the use of an optical telescope and sent to a gated diode-array spectrometer where the characteristic fluorescence spectral signature is resolved. The fluorescence data are analyzed in real-time and any oil contamination detected is classified into one of three broad categories: light-refined, crude, or heavy-refined. Maps depicting the oil contamination and the amount of coverage are shown on the operator's display and printed out on the aircraft for delivery to spill response personnel.

Laser fluorosensors are active sensors, which means they provide their own source of excitation or illumination. As such, laser fluorosensors that incorporate range-gated detection systems can operate during conditions of full sunlight or in total darkness.



The operator's display and printer of the Scanning Laser Environmental Airborne Fluorosensor, or SLEAF, as installed inside the DC-3. Maps showing the oil contamination and the amount of oil coverage are shown on the display and printed out for use by spill response personnel.

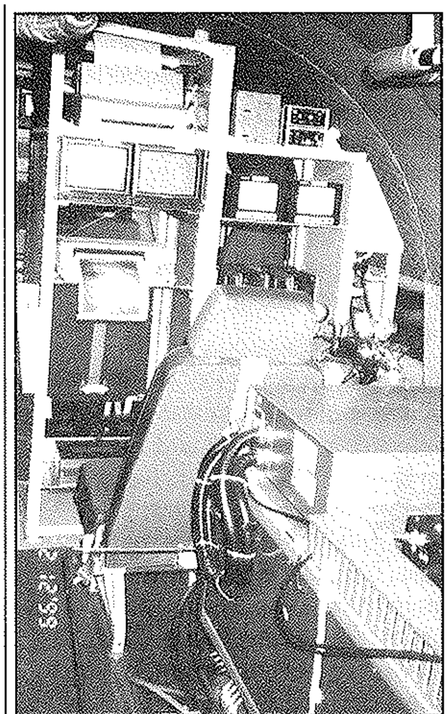


This photo shows the two scanner heads on the Scanning Laser Environmental Airborne Fluorosensor or SLEAF. The wide-swath scanner head is on the top and the narrow-swath scanner head is on the bottom. These scanners provide the wide/narrow cross-track coverage required for investigating oiled shorelines.

More information on the SLEAF system is available in several recent publications (Brown and Fingas, 1998a,b; Brown et al., 1998).

A Reliable Workhorse

From 1992 to mid-1999, the DC-3 housed the prototype Laser Environmental Airborne Fluorosensor (LEAF). The LEAF system was developed to provide real-time, unambiguous detection



The Scanning Laser Environmental Airborne Fluorosensor (SLEAF) and aft equipment rack in the DC-3.

of oil in the marine environment. Although the LEAF system is very sensitive, it is inherently a nadir-looking, small field-of-view (FOV) sensor. This limitation is detrimental when searching for oil contamination along beaches and coastlines where oil can pile up in narrow bands at the high-tide line. It was one of the leading factors in the decision to develop a scanning laser fluorosensor system.

During its tenure, the LEAF was modified periodically through the addition of a dye laser to emit light at blue-green wavelengths in the visible spectrum for the monitoring of chlorophyll and dissolved organic material. The LEAF system is still operational and can be reinstalled in the DC-3 if required for a particular mission.

In addition to the primary laser fluorosensor system, the DC-3 houses several wide field-of-view sensors including infrared (IR), ultraviolet (UV), and visible down-looking cameras and will soon house a side-looking airborne radar (SLAR). A Wild RC-10 large format reconnaissance camera can be positioned in one of the sensor bays to photograph marine or terrestrial targets with a variety of film including standard colour, black and white, or false-colour infrared.

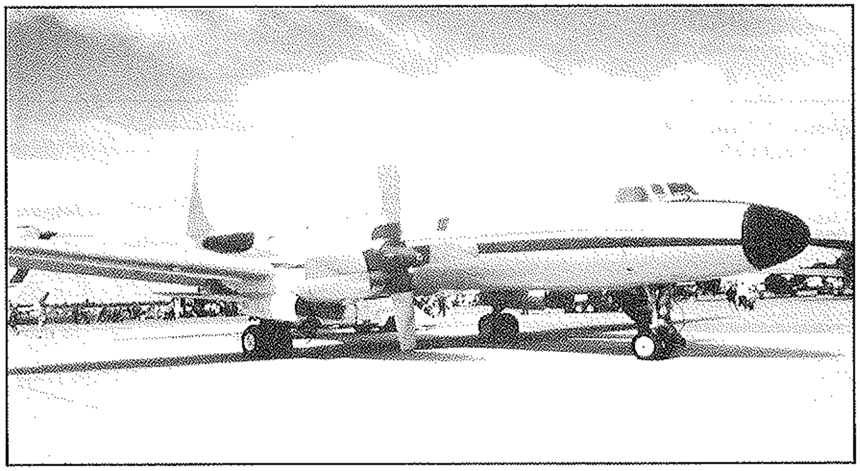
Over the years, the DC-3 has been used as a platform to test a multitude of research and development sensors, including laser acoustic systems, laser fluorosensors, lidar bathymeters, radar, infrared, optical, and microwave sensors. The DC-3's size, available sensor bays, and electrical power supply, combined with the fact that it is an unpressurized aircraft, make it a reliable workhorse for sensor development.

The aircraft has been deployed on all three Canadian coastlines and has recently been involved in projects such as stereo-photography around the proposed Voisey's Bay mining site, the raising of the *Irving Whale* oil barge in the Gulf of St. Lawrence, overflights of natural oil seeps in Santa Barbara, California, and the Swissair Flight 111 crash investigation last year.

The Convair-580

The other aircraft owned by the Emergencies Science Division is the Convair-580 or C-GRSC. It was built as a model 340 by the Convair Division of General Dynamics in 1953 and converted to a model 580 (s/n 72) in 1962. ESD acquired the Convair-580 Synthetic Aperture Radar (SAR) facility from the Canada Centre for Remote Sensing in 1996.

Today, the Convair-580 functions as both an operational platform for collecting SAR data and as a research and development platform for new and improved airborne and satellite SAR sensors.

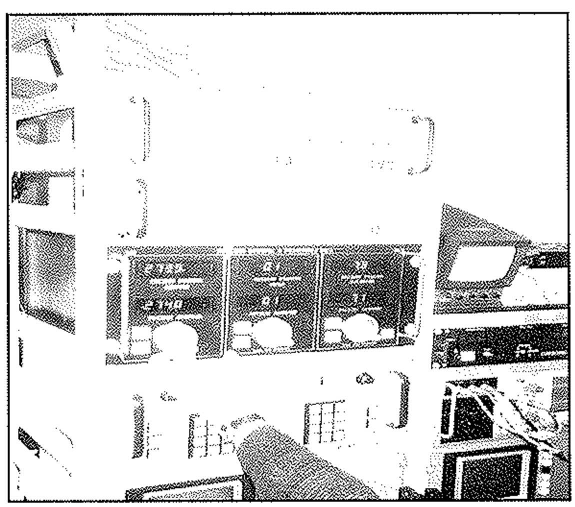


The Convair-580 was built as a model 340 by the Convair Division of General Dynamics in 1953 and was converted to a model 580 in 1962. The Emergencies Science Division acquired the aircraft from the Canada Centre for Remote Sensing in 1996. It is equipped with two world-class Synthetic Aperture Radars (SARs) with interferometric and polarimetric imaging capabilities.

The Convair-580 aircraft is equipped with C- and X-band Synthetic Aperture Radars (SARs), equipped with dual-channel receivers. Imaging is possible on either side of the aircraft in nadir (0 to 74° incidence angle), narrow (0 to 76°), or wide-swath (45 to 85°) operating geometries.

Furthermore, the range gate delay can be varied to change the starting incidence angle so that any swath location can be chosen relative to the aircraft position.

The aircraft is normally flown at an altitude of 21,000 feet, although this can be varied. At this altitude, high-resolution (6 x 6 m) real-time imagery can be produced in nadir (22 km) or narrow (18 km) swaths and low resolution (20 x 10 m)



Inside the Convair-580, the operator is shown at the control unit adjusting the antenna position of the main Synthetic Aperture Radar (SAR) station.

imagery can be produced in a wide swath of 63 km. The system provides both real-time and signal data.

In the real-time mode, the processor provides digital motion compensation across the swath. The azimuth processor produces dual-channel, half-swath and single-channel full-swath imagery that is displayed on video monitors and recorded onto dry-silver paper and a video cassette recorder.

The digitized real-time images are also recorded onto Exabyte tapes for post-flight analysis. Raw (range-compressed) signal data are recorded on digital video tape with a helical scan recorder for precision processing and image creation. All radar parameters and navigation information are recorded onto Exabyte tape.

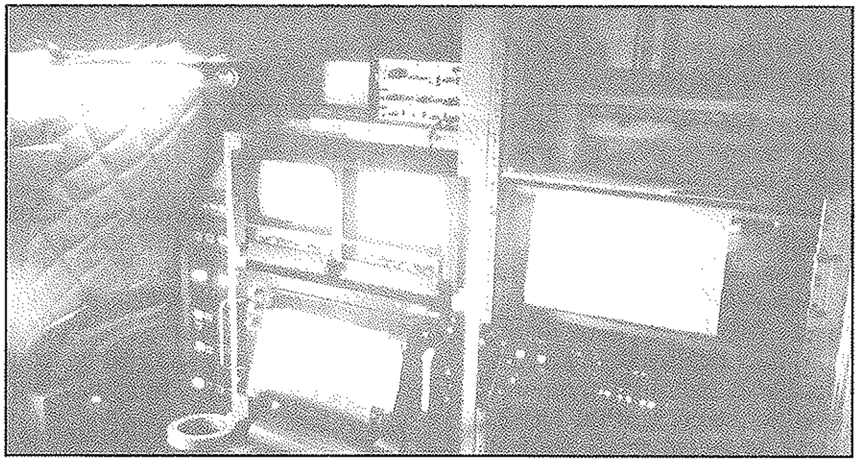
The Convair-580 SAR facility provides reliable and accurate scene calibration, temporal and spatial interferometric modes, a C-band four-polarization imaging mode, and a C-band polarimetric mode. Two protective radomes on the outside of the aircraft house the C/X-band antenna system and the C-band interferometric antenna.

The SAR facility has provided quantitative data for a myriad of applications including sea ice studies, oceanography, hydrology, geology, agriculture, and pollution monitoring. The system has been used as a testbed for developing SAR data processors, algorithm development, the simulation of satellite SAR systems (e.g., Radarsat-1, ERS-1), and the development of new SAR modes (polarimetric and interferometric).

The Convair-580 SAR facility has flown many hundreds of imaging hours in Canada, the United States, Europe, Asia, Africa, and South America. It has participated in several national and international programs to develop radar remote sensing applications. These include the Labrador Ice Margin Experiment (LIMEX 87 and LIMEX 89), the Labrador Extreme Waves Experiment (LEWEX 87), the Norwegian Coastal SAR Experiment (NORCSEX 88), the Grand Banks Experiment 91, the South American SAR Experiment (SAREX 92), and GlobeSAR.

GlobeSAR was instrumental in introducing the remote sensing community to the upcoming capabilities of the Radarsat-1 satellite. The Convair-580 SAR facility had the unique capability of collecting data that simulated the data that would be collected with the satellite (before its launch in 1996).

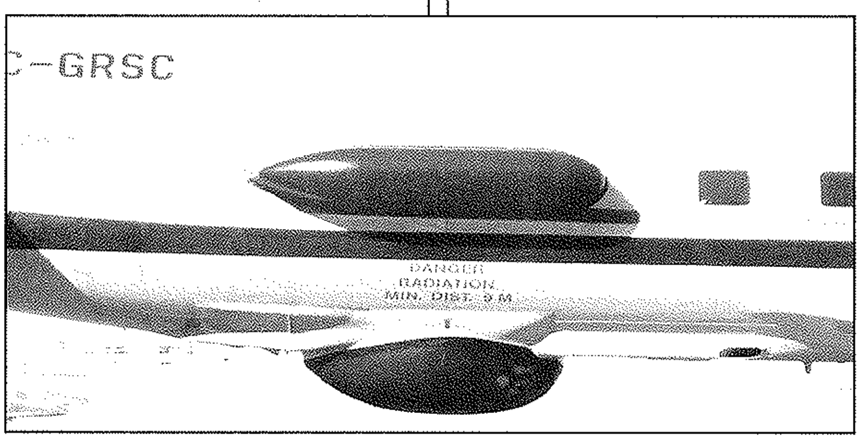
Extensive details on the Convair-580 SAR facility can be found in Livingstone et al., 1995.



This photo shows the real-time operator's station onboard the Convair-580. The azimuth processor produces dual-channel half-swath, and single-channel full-swath imagery that is displayed on video monitors and recorded onto dry-silver paper and a video cassette recorder.

Swissair Flight 111

One of the aircrafts' higher profile missions was their use in response to the Swissair Flight 111 tragedy off Peggy's Cove,



Protective radomes on the exterior of the Convair-580 house the conventional C-/X-band antenna (lower) and the C-band interferometric antenna (upper).

Nova Scotia in 1998. The DC-3 and Convair-580 worked together on this mission.

The Convair-580 SAR was able to rapidly image large areas of the ocean around the crash site and to the north around St. Margaret's Bay and Mahone Bay in an attempt to locate debris fields and petroleum slicks from the downed Swissair MD-II. The SAR facility was usually deployed in advance of the DC-3 and mission reports relayed to the crew of the DC-3. Several suspected debris fields were observed in the SAR real-time imagery and the DC-3 was deployed to further investigate the anomalies.

The DC-3 also helped to decipher one of the many questions surrounding the crash of Swissair Flight 111 - the possibility of fuel being dumped prior to an attempted emergency landing.

Two remote sensing techniques were used to search for evidence of fuel dumping. The first was to use the LEAF to look for Jet-A fuel over the suspected flight path of Flight 111. The second technique was to employ false-colour infrared film (Kodak Aerochrome II 2443) to look for vegetation stress that could result from exposure to Jet fuel. When vegetation is stressed, one of the first signs is a decrease in infrared reflectance, which can be observed in infrared photography.

Conclusion

Both ESD's remote sensing aircraft will continue to be active in the new millennium. The DC-3 will be involved in test/demonstration flights of the SLEAF in the Gulf of Mexico and along the east coast of Canada in late 1999 to early 2000.

The Convair-580 will continue to fly for clients in the public and private sectors, performing both R&D missions involving collecting interferometric and polarimetric data and responding to environmental emergencies. With its polarimetric and interferometric capabilities, the Convair-580 SAR facility is once again positioned to be a testbed for the next generation of radar sensors and satellites.

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