A Modular Multispectral Scanner System for UAV Applications

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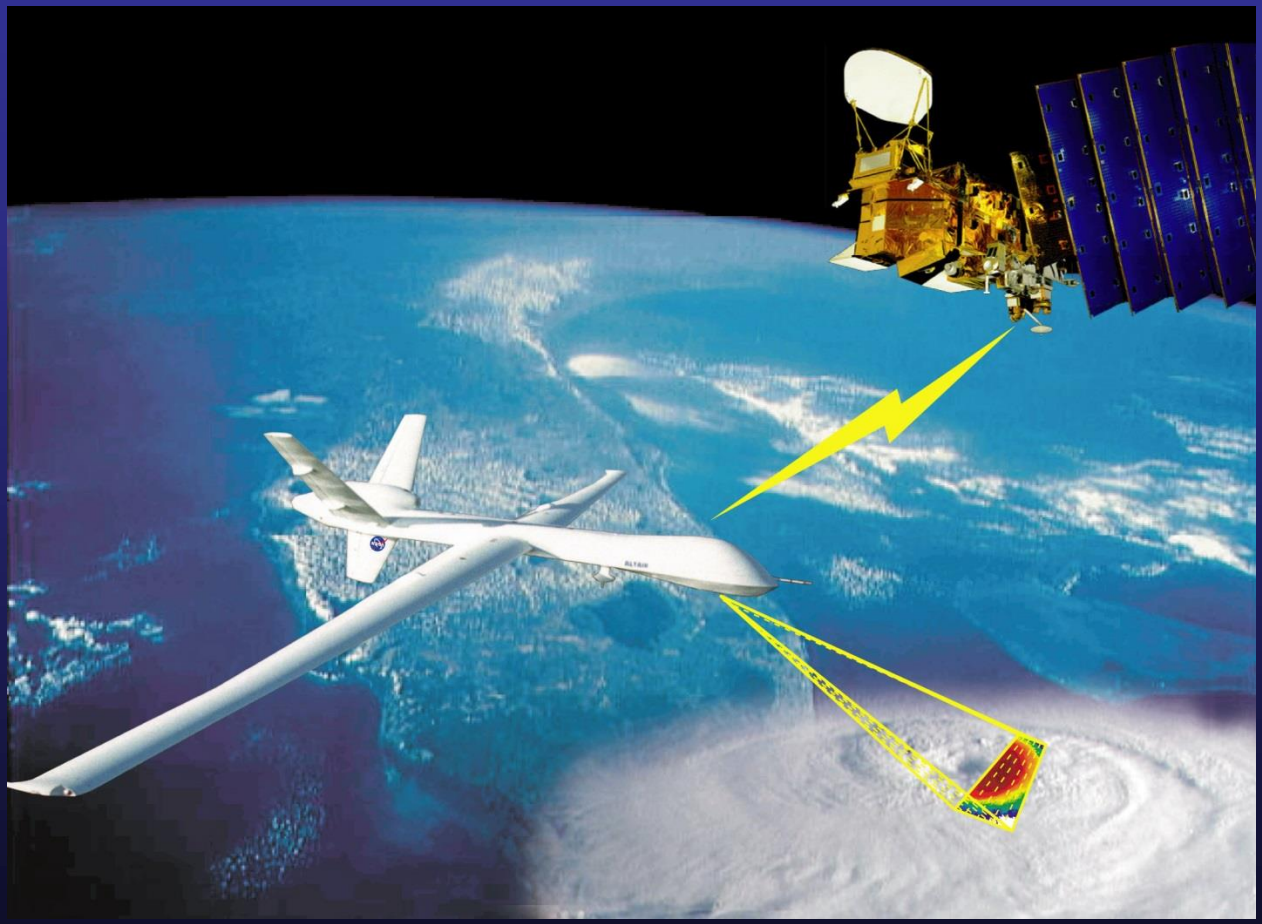
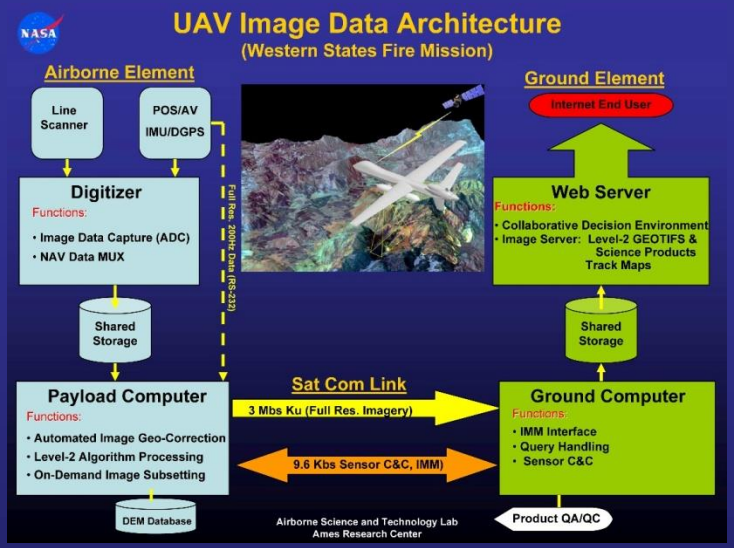


Airborne Science Program

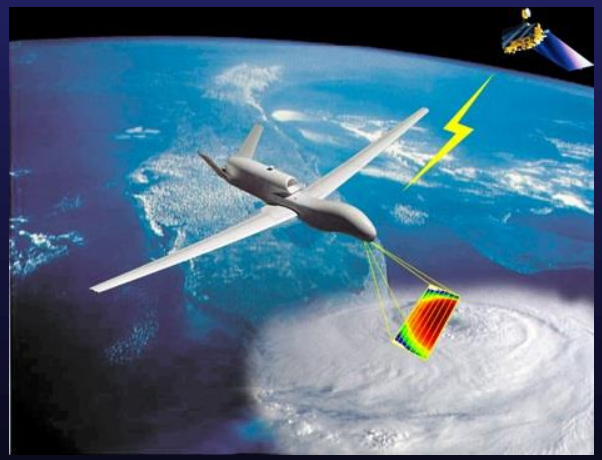
University Affiliated Research Center

The UAS Autonomous Modular Sensor (AMS)
a development platform for airborne sensor web technologies

- Multiple spectral configurations
- Onboard Level-2 product generation
- Embedded precision navigation system
- Real-time data telemetry interface
- Hardware development funding from the NASA HQ Airborne Science Program



The WSFM Real-time Data Environment

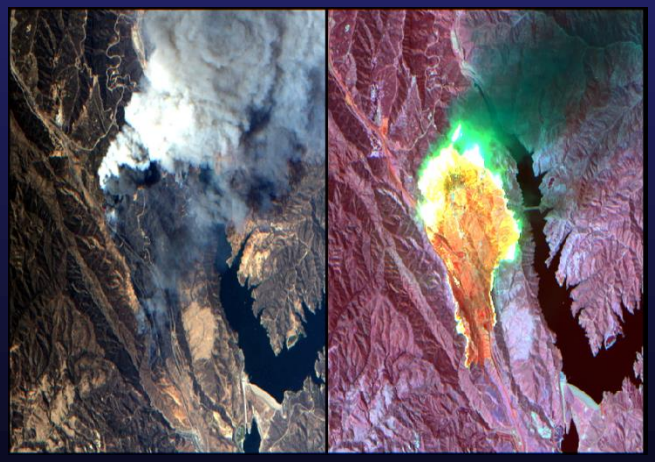


AMS Sensor Pod on Ikhana

A New Modular Sensor System for UAV Operations with Three Configurations

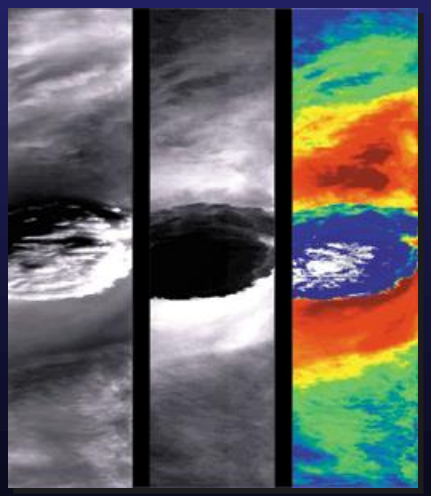
- Wild Fire Sensor
- Atmospheric Mapping Sensor
- Ocean Color Imager
- Shared Scanning Optics and Data Modules
- Compatible with Predator-B, Global Hawk, etc.

General Atomics Altair UAV



Wild Fire Research (TMS example)

Ocean Color / Coral Reef Research (AOCI example)



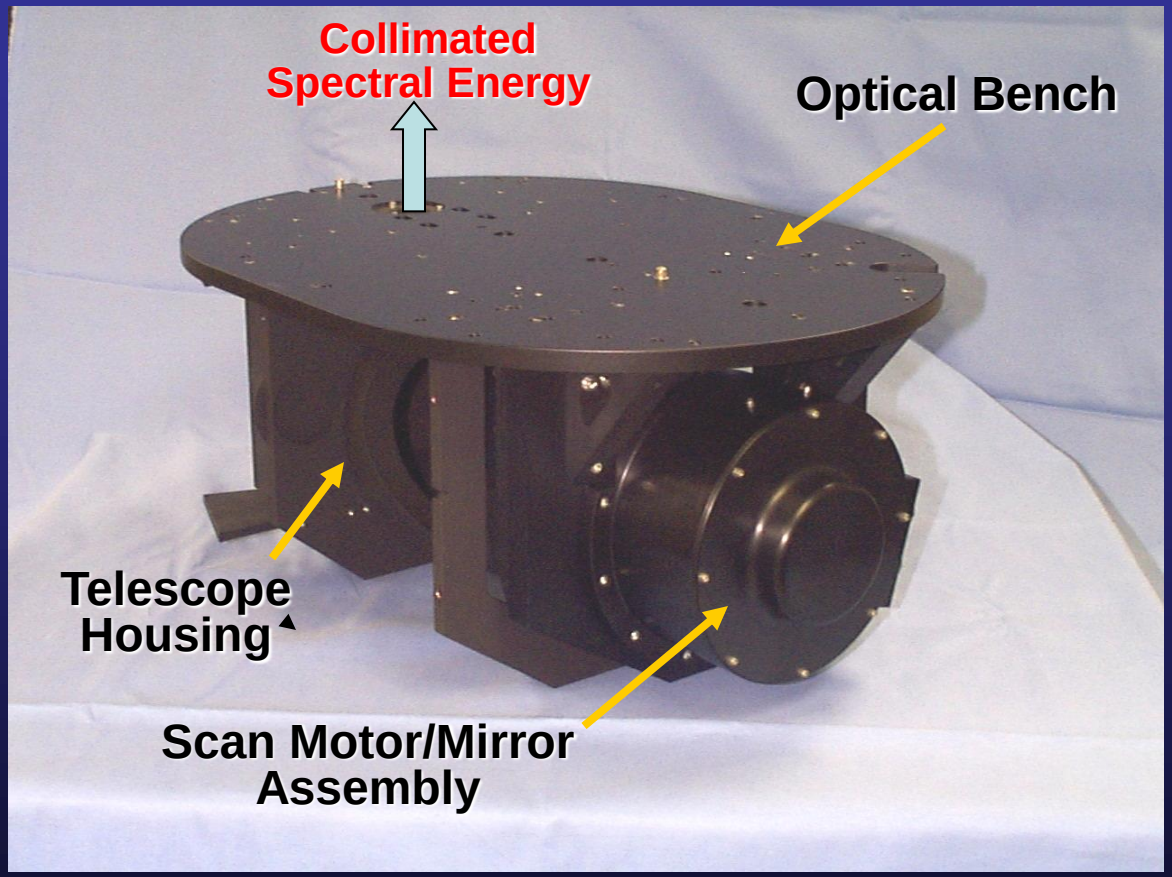
Hurricane and Atmospheric Studies (MAMS example)

Airborne Sensor Facility
Ames Research Center

UAV AMS Sensor Features

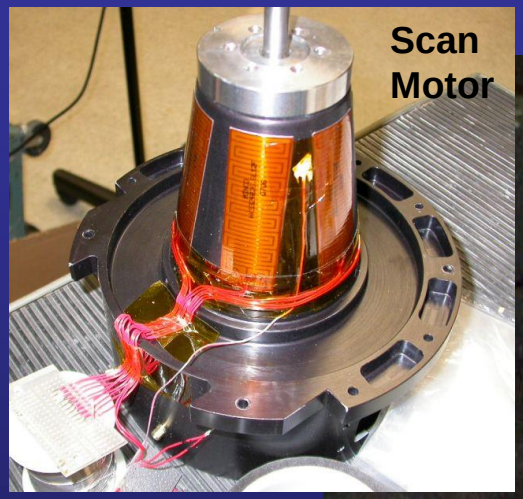
- Pressurized Electronics Packaging
- 16-bit Digitizer w/ Auxiliary CPU
- Customized Daedalus AADS-1268 Spectrometer
- Sterling & TE-Cooled IR Detectors
- New Scanning Optics Module
- Solid State Storage Media
- Multi-Platform Compatibility (UAV, Manned)
- Long-Duration Autonomous Operation

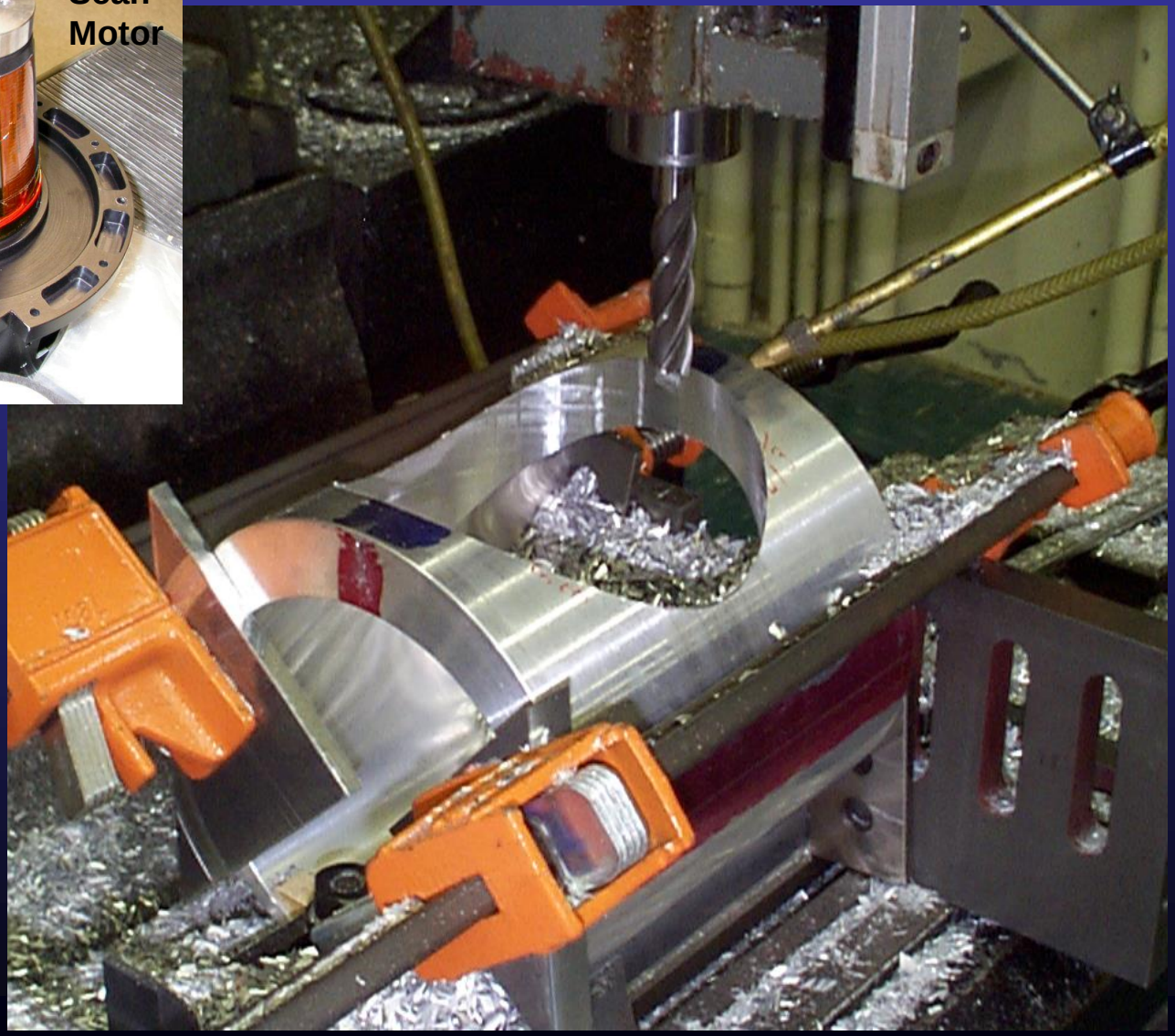
Common Opto-Mechanical Module



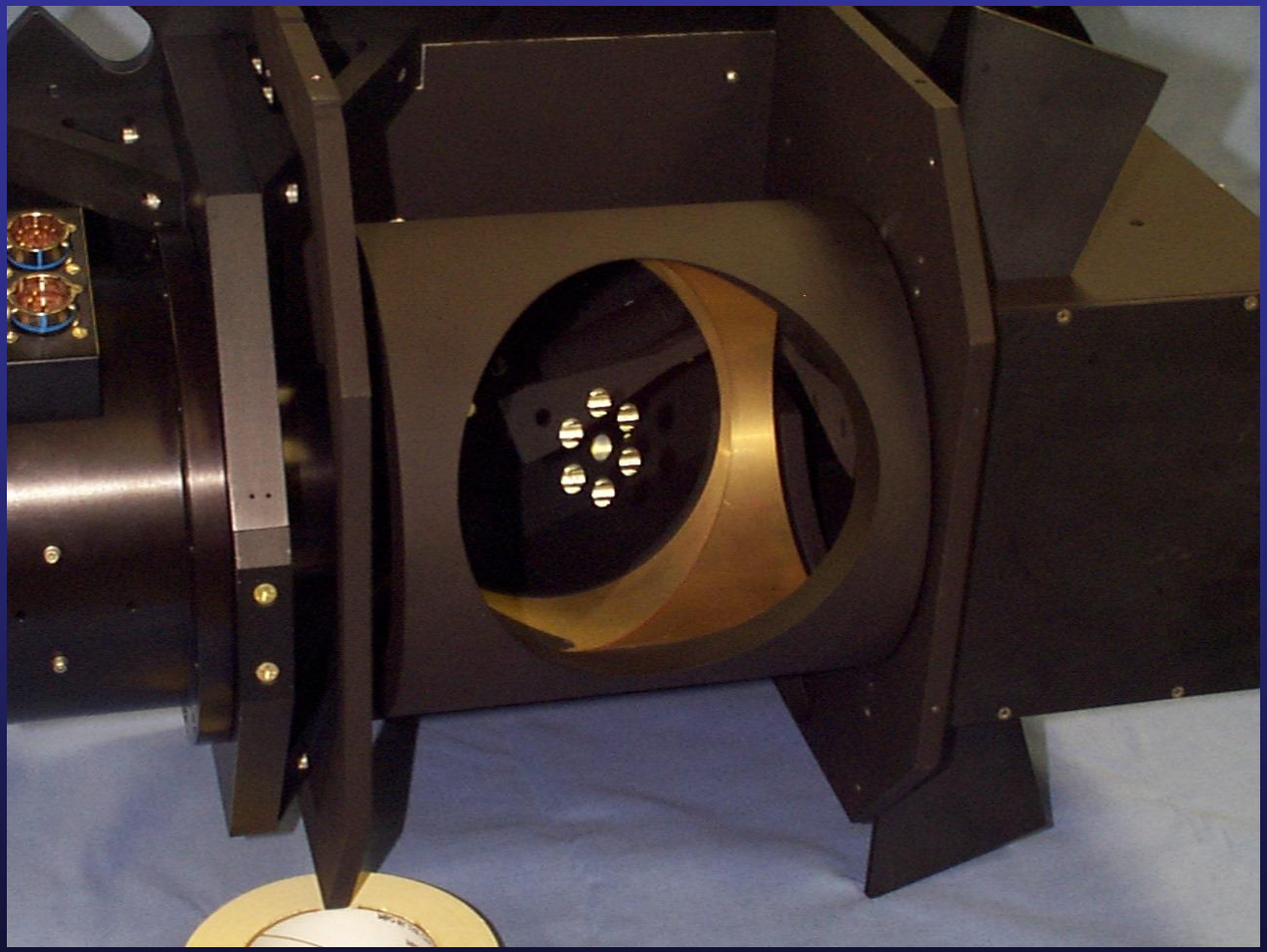
(Interfaces to the Wildfire, OCI, or AMS Spectrometers)

Scan Mirror Fabrication





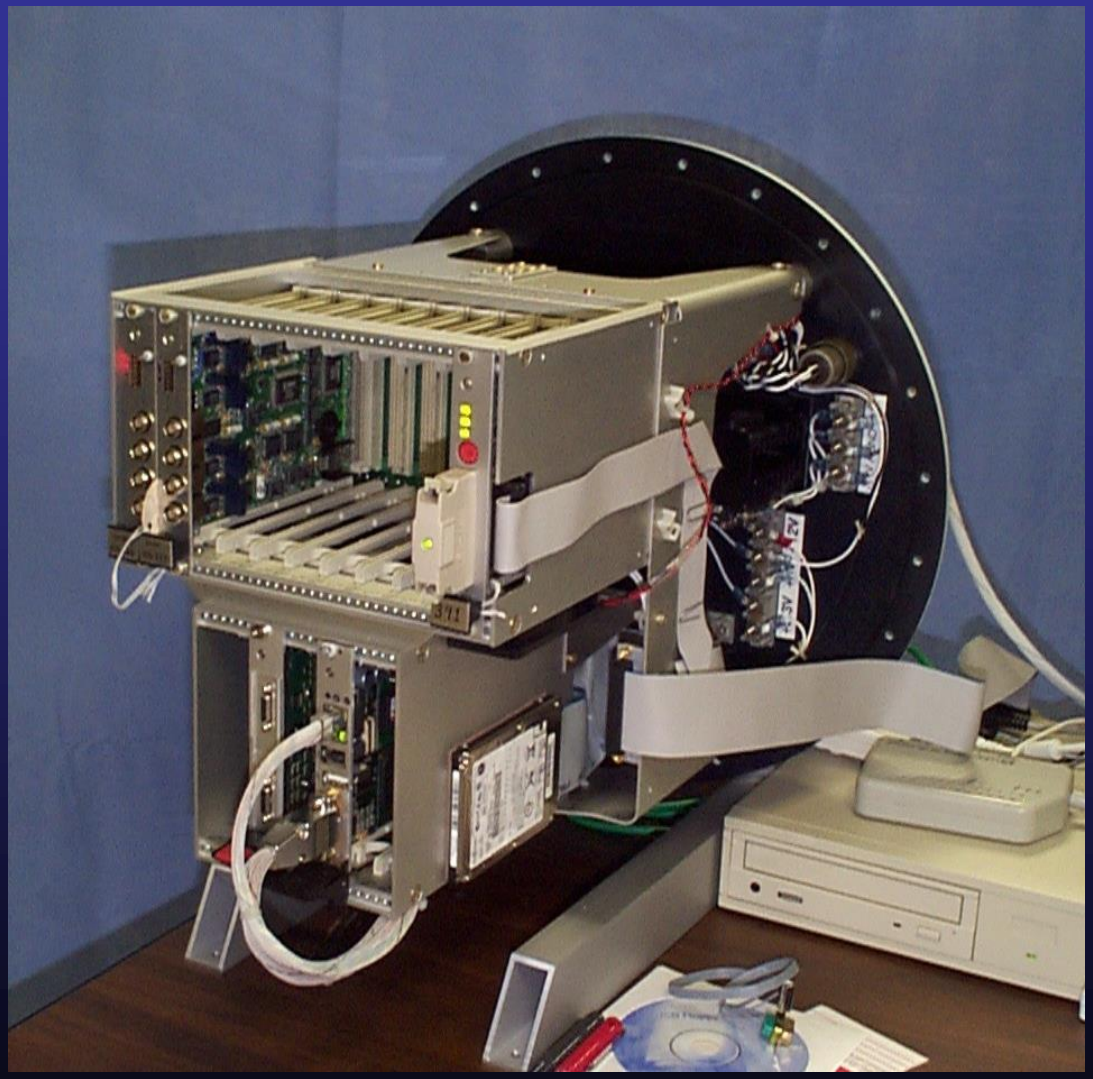
New Scan Mirror Assembly



(Includes motor, elliptical scan mirror, shroud, and shaft position encoder)

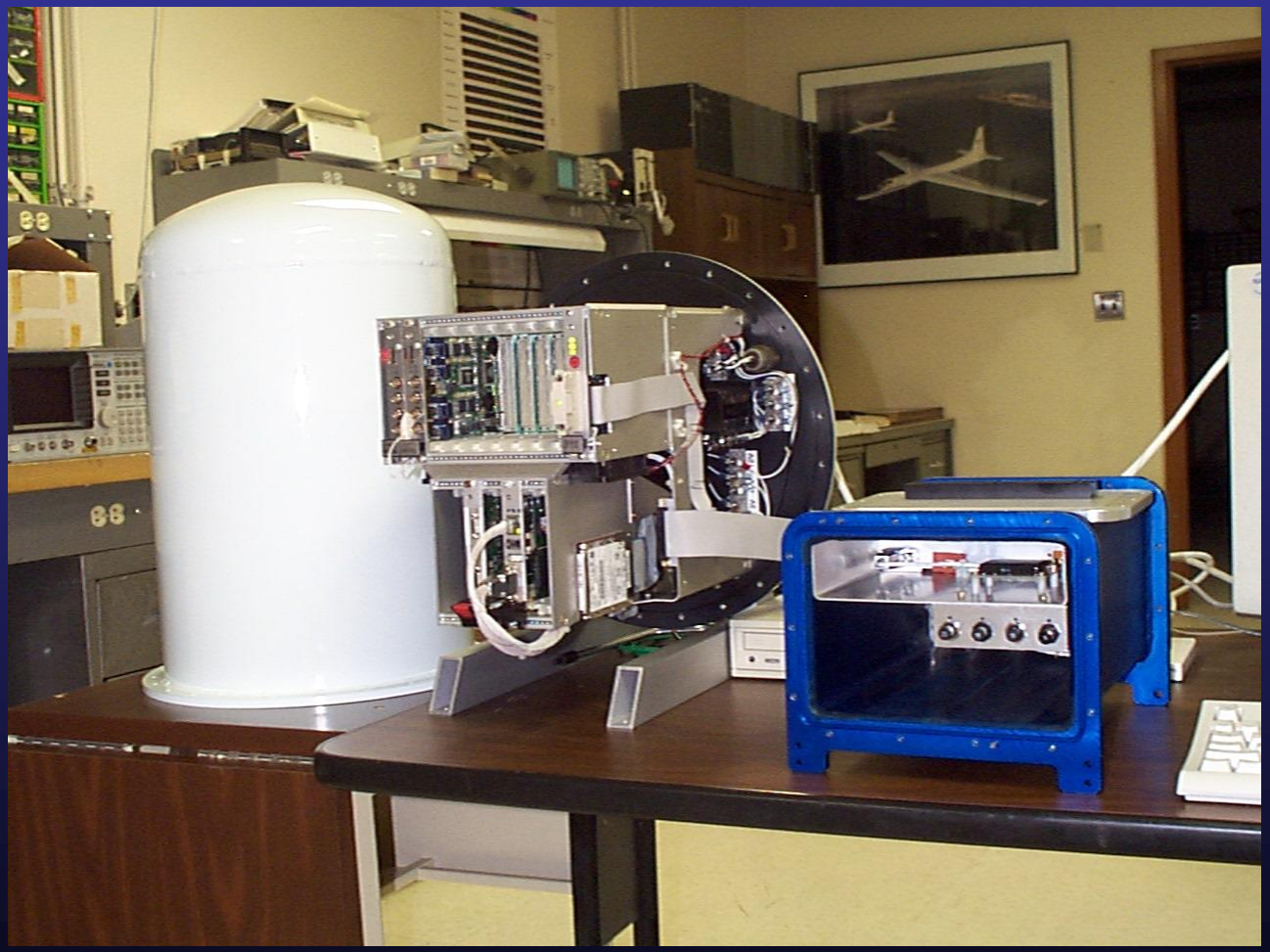
Digitizer and Data System

(Pressure Housing Removed. Card Cages Not Fully Populated)



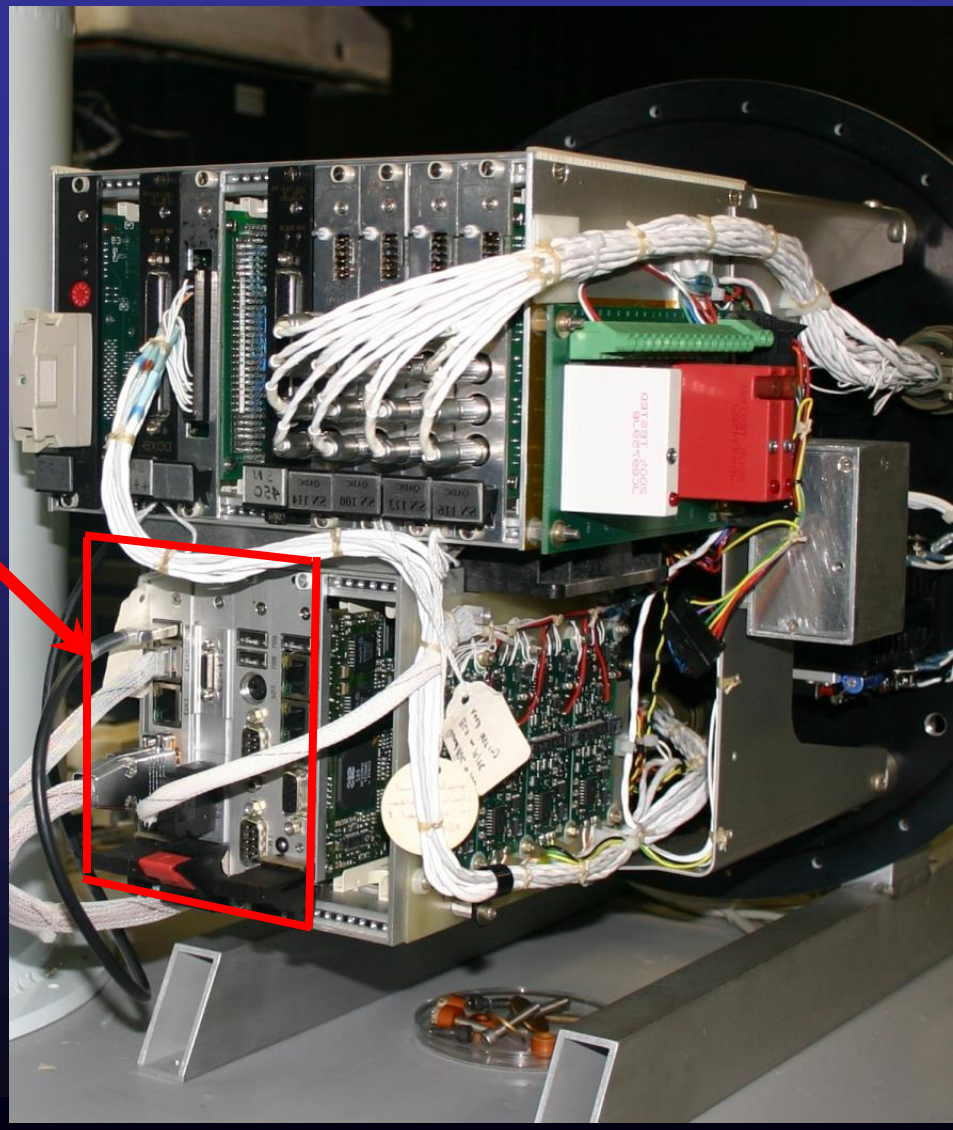
UAV Sensor Data System

with Pressure Housings and Scan Motor Controller



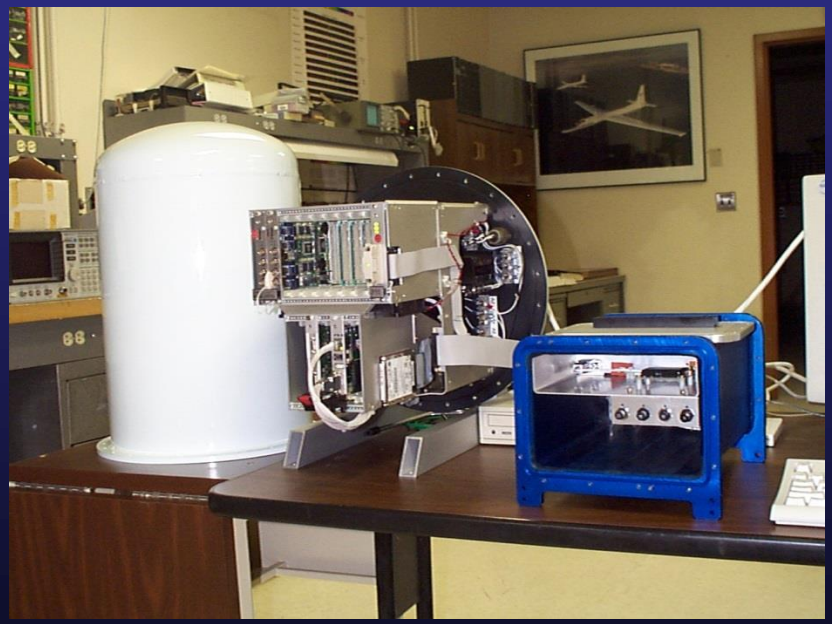
UAS Science Mission Computer

- A Universal Payload Interface to High-Bandwidth Telemetry Systems
- Inputs for >20 instruments; Up To 40 Mbs Throughput
- Fast CPU & Solid State Storage For Experimenter Data & Algorithms
- Real-time on-board generation of Level-1 & 2 geophysical products, Geo-Tiffs and JPG-2000s
- Embedded SRTM Digital Elevation Model of the Western U.S.
- Interface to ground-based IMM/Collaborative Decision Environment
- Future stand-alone packaging for Global Hawk



AMS System

Data System



Scanhead - Wildfire Configuration

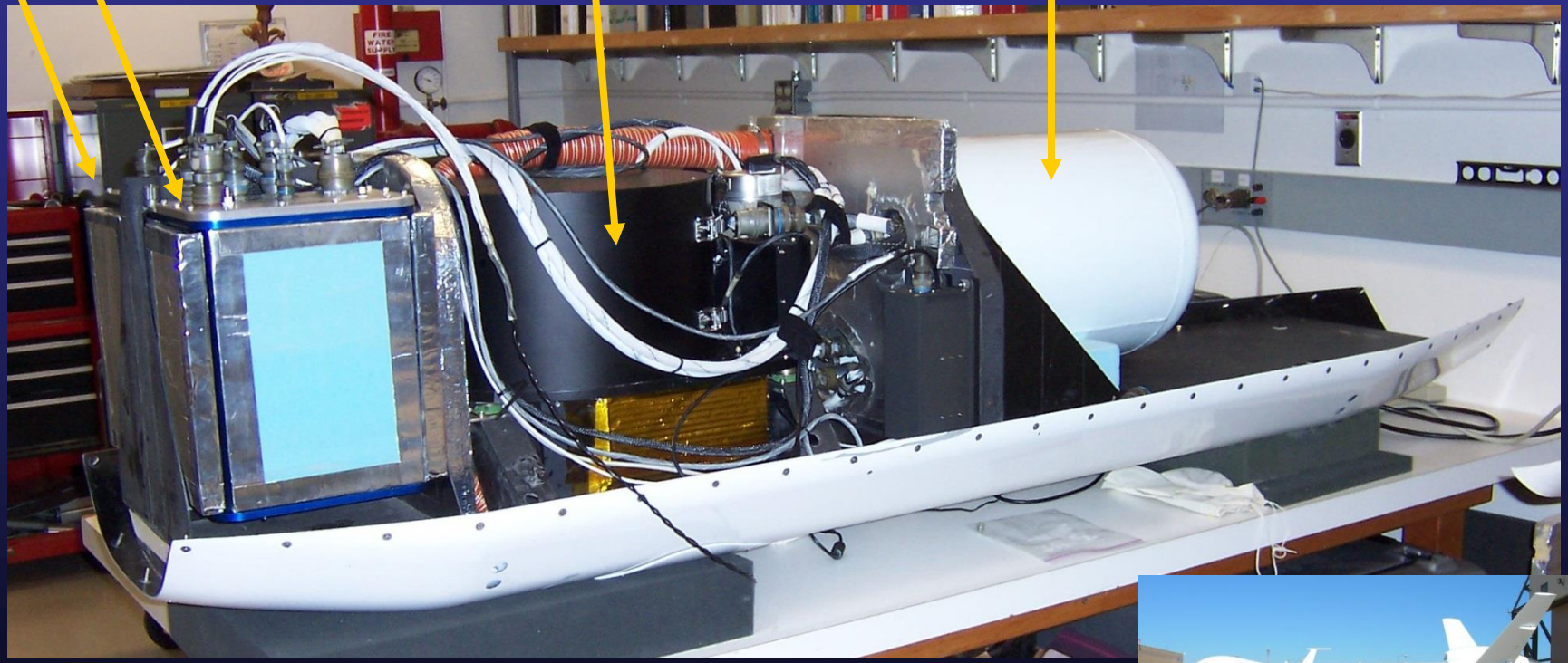
(covers removed)

AMS System Components on Pod Tray

Two environmental enclosures (data disks & GPS; and power supplies & controllers)

Scan Head

Data System Enclosure



AMS System Weights	
Scan Head Assembly	**Wt. (lbs)**
Scan Head	136.4
Total	**136.4**
Ancillary Equipment	
Data System and Enclosure	43.2
Motor Driver	10.5
BB Controller	4.4
Power Distributor	20.24
Applanix Enclosure	22.44
Ag132 DGPS Receiver	22.0
Cabling	7.92
Heater/blower	1.76
Total	**132.46**
Total AMS System Weight	**268.86**

UAV Wildfire Mapping Sensor

(Utilizes a modified Daedalus AADS-1268 spectrometer)

Band	Wavelength μm	
1	0.42- 0.45	
2	0.45- 0.52	(TM1)
3	0.52- 0.60	(TM2)
4	0.60- 0.62	
5	0.63- 0.69	(TM3)
6	0.69- 0.75	
7	0.76- 0.90	(TM4)
8	0.91- 1.05	
9	1.55- 1.75	(TM5)
10	2.08- 2.35	(TM7)
11	3.60- 3.79	(VIIRS M12)
12	10.26-11.26	(VIIRS M15)

Total Field of View: 42.5 or 85.9 degrees (selectable)
IFOV: 1.25 mrad or 2.5mrad (")
Spatial Resolution: 3 – 50 meters (variable)

NASA UAS Ocean Color Imager

- UAS or Conventional Aircraft-Compatible
- Includes SeaWiFS Bands + Thermal IR for SST
- Variable Resolution (2 – 50 meters, altitude dependent)
- Highly Calibrated
- Successor to NASA Daedalus AOCI

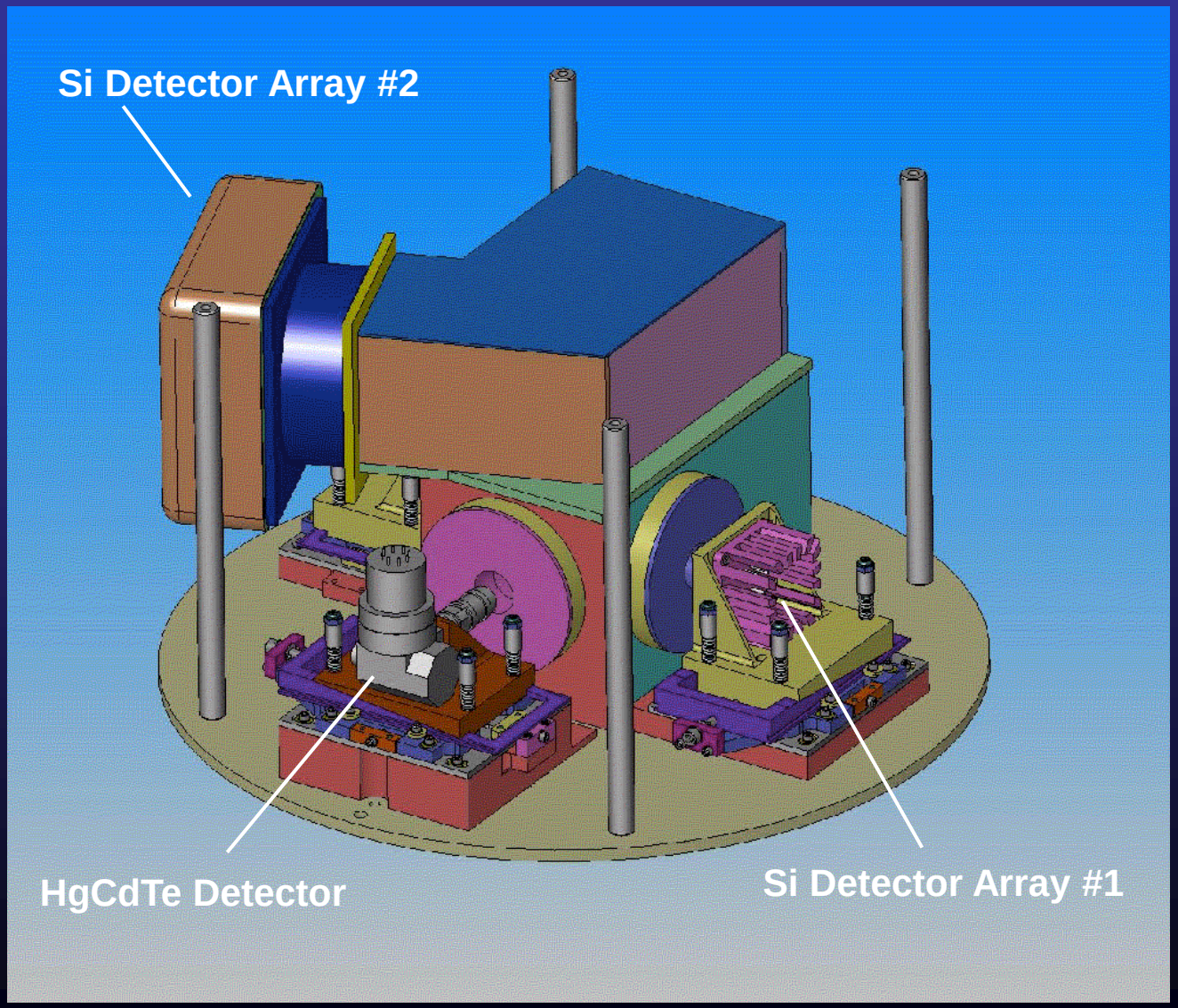
Band	λ nm	Δ λ nm
1	412*	20
2	443*	
3	490*	
4	510*	
5	555*	
6	620	
7	670*	
8	770*	60
9	860*	"
10	1024	"
11	11.5μm	4μm

*SeaWiFS Bands

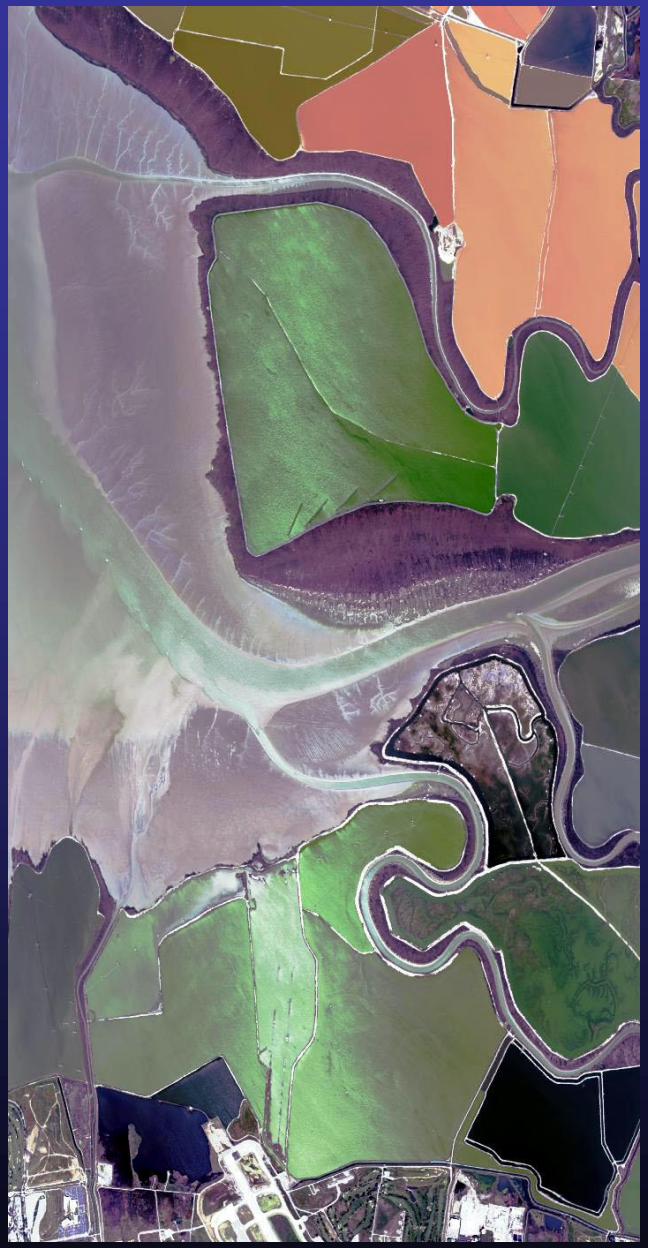
S.F. Bay Salt Ponds
AMS Image (4/06)

Aircraft Platforms:
Ikhana or Global Hawk UAS, ER-2, WB-57, B200, Cessna Caravan

The OCI Spectrometer



S.F. Bay AMS 4/06



Natural Color

Thermal IR

AMS Atmospheric Mapping Configuration

Band	Wavelength, μm	
1	0.45 - 0.52	
2	0.52 - 0.60	
3	0.57 - 0.67	
4	0.60 - 0.73	
5	0.65 - 0.83	
6	0.72 - 0.99	
7	0.83 - 1.05	
8	6.54 – 6.90	(MODIS 27)
9	10.26 – 11.26	(NPOES VIIRS M15)
10	11.54 – 12.49	(NPOES VIIRS M16)

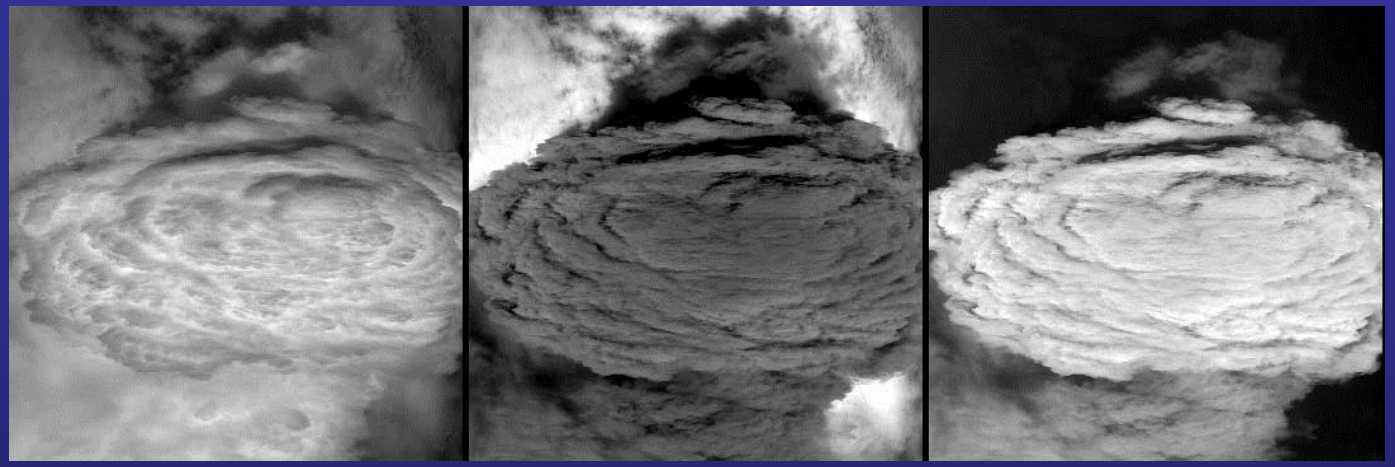
Field of View: 85.9 degrees
IFOV: 2.5
Spatial Resolution: 50 meters from 19.8 km

AMS H2O Vapor Configuration

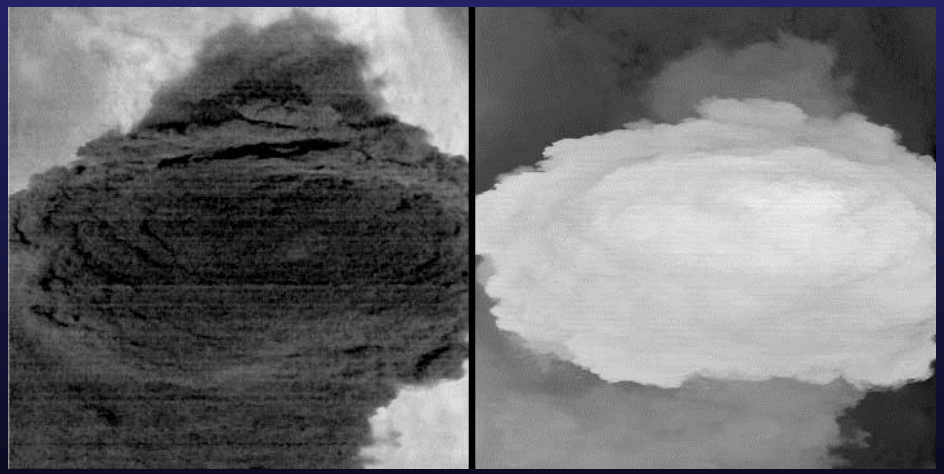
Band	Wavelength μm	
1	0.42- 0.45	
2	0.45- 0.52	(TM1)
3	0.52- 0.60	(TM2)
4	0.60- 0.62	
5	0.63- 0.69	(TM3)
6	0.69- 0.75	
7	0.76- 0.90	(TM4)
8	0.91- 1.05	
9	1.36 - 1.39	(MODIS 26)
10	1.86 - 1.91	(MAS 15)
11	6.54 - 6.90	(MODIS 27)

Total Field of View: 85.9 degrees
IFOV: 2.5mrad
Spatial Resolution: 50 meters (variable)

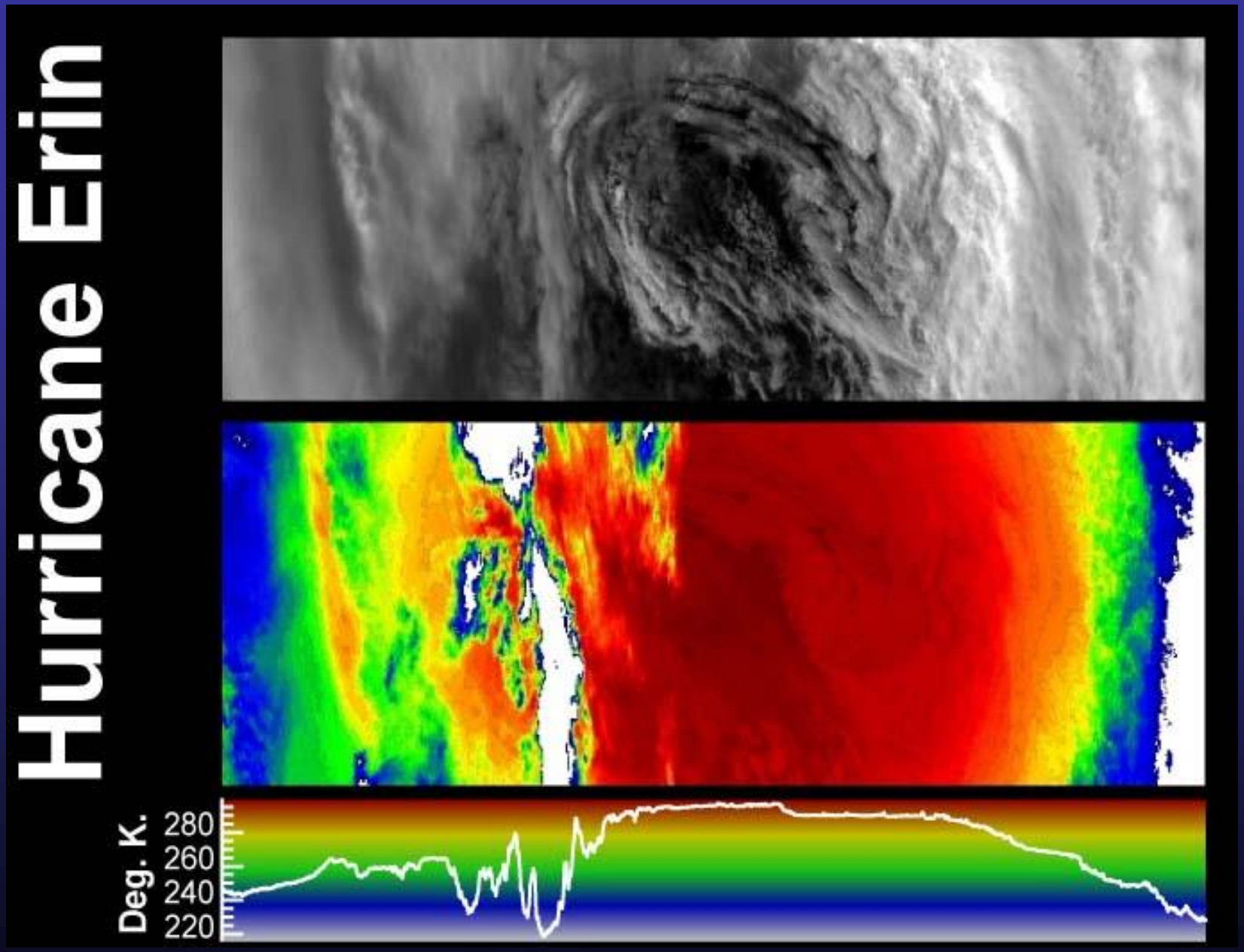
Representative Imagery: ER-2 MAS Convective System (CAMEX, 9/7/01)



0.65 μm 1.62 μm 1.88 μm



3.75 μm 10.85 μm



Representative Imagery: ER-2 MAMS Data

ASF Calibration Lab

NIST-Traceable Spectral and Radiometric Calibration Services for Airborne Sensors

Currently supporting:

AMS

eMAS and MASTER

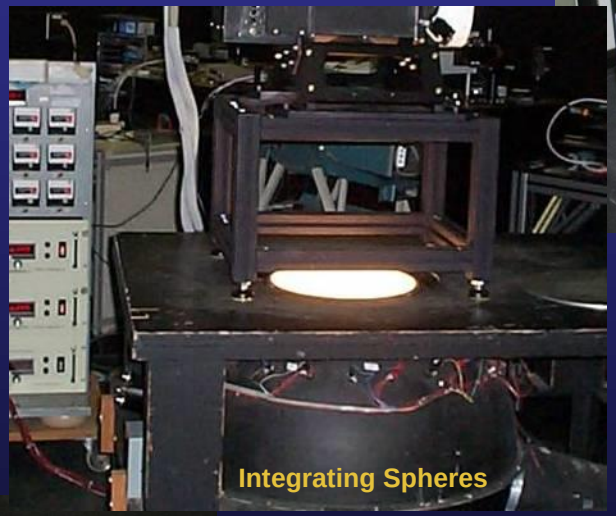
SSFR (Solar Flux Radiometer)

AATS-14 (Sun Photometer)

4-STAR " "

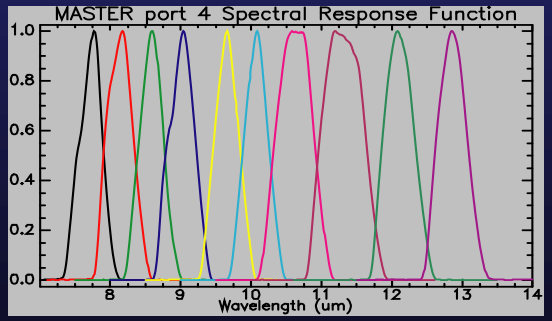
CAR, RSP (Radiometers)

Field Spectro-Radiometers



Ref. Paper:

Radiometric Validation of NASA ARC Calibration Laboratory, S. Brown, C. Johnson, et al. Applied Optics/Vol.44, No. 30, Oct. 2005



AMS as a Sensor Web Software Development Platform

Real-time merge of MODIS and AMS Fire-Detects

UAS-AMS Image Data Flow Diagram

(Western States Fire Mission, 8/06)

Airborne Element

Line Scanner

POS/AV IMU/DGPS

Digitizer

- Image Data Capture (ADC)
- POS-AV Data Ingest

Shared Storage

Full Res. 200Hz Data (RS-232)

Science Mission Computer

- Ku-Band Telemetry Interface
- Level-1B, -2 Product Generation
- Image Geo-Rectification
- SRTM DEM Database

Ku Sat Com Link

3 Mbs Link (Forward Only)

9.6Kbs Duplex Channel

Ground Element

CDE Agents

Web Server

- Collaborative Decision Environment (CDE) Host
- Intelligent Mission Management SW
- Image & Map Server

Shared Storage

Ground Computer

- Instrument C&C
- Query Handling
- Instrument Engineering Data
- Vehicle Data
- Product QA/QC

Operational Legacy

University Affiliated Research Center

Airborne Sensor Facility

- The Scan Head (opto-mechanical sub-system) has flown over 400 flight hours on the ER-2 (as TMS, AOCI, MAMS)
- The AMS system flew 51 NASA missions on the Cessna C-208, Altair and Ikhana Predator UAS, and the ER-2, between April 2006 and Feb 2013.
- AMS sensor development was originally funded by the Suborbital, and later Airborne, Science Programs, initiated by Cheryl Yuhas, PM

Altair 2006 Western States Fire Missions

C209 AMS Test Flights, 2006-7

The AMS as Test-Bed

The AMS was intended as a test-bed for the development of the hardware subsystems and software architectures required for the future airborne sensor web.

The AMS project has produced the following capabilities:

1. **A universal payload computer, with high-speed telemetry interfaces**
2. **Real-time onboard science databases, accessible from the ground**
3. **Remote instrument command and control protocols**
4. **Onboard Level-2 product generation using experimenter algorithms**
5. **Interfaces to a global geo-spatial data and decision-making environment, providing raster, vector, and numerical data streams**

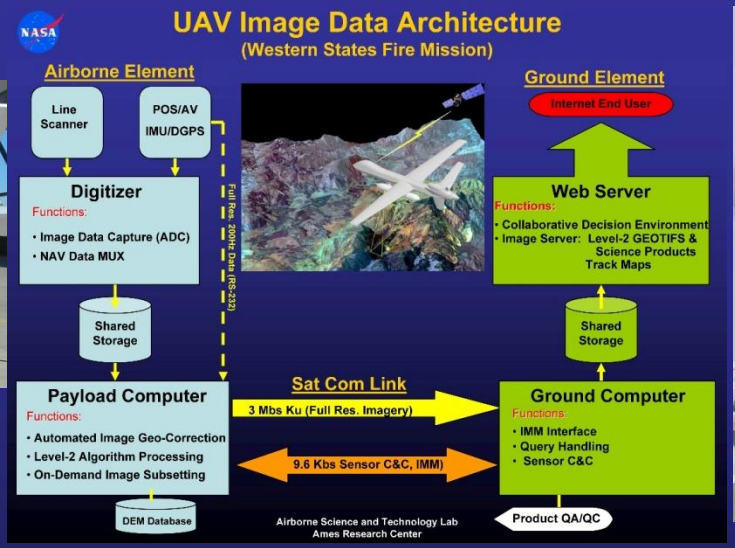
All of these technologies have been implemented on the Global Hawk/GHOC, as demonstrated on GLOPAC and GRIP (2010)

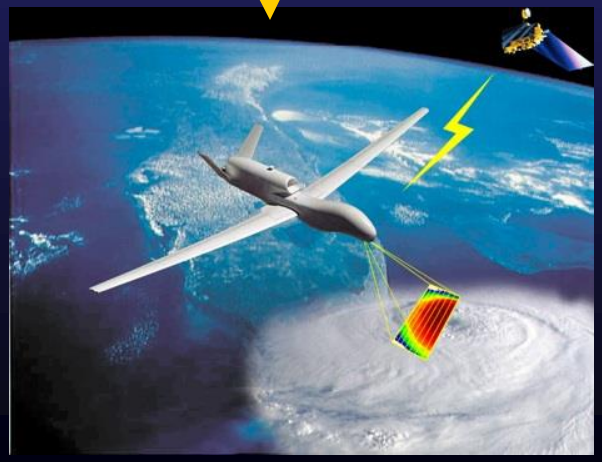
The Legacy of AMS as an Airborne Systems Development Platform

The AMS subsystem designs later used on the eMAS and MASTER instrument projects:

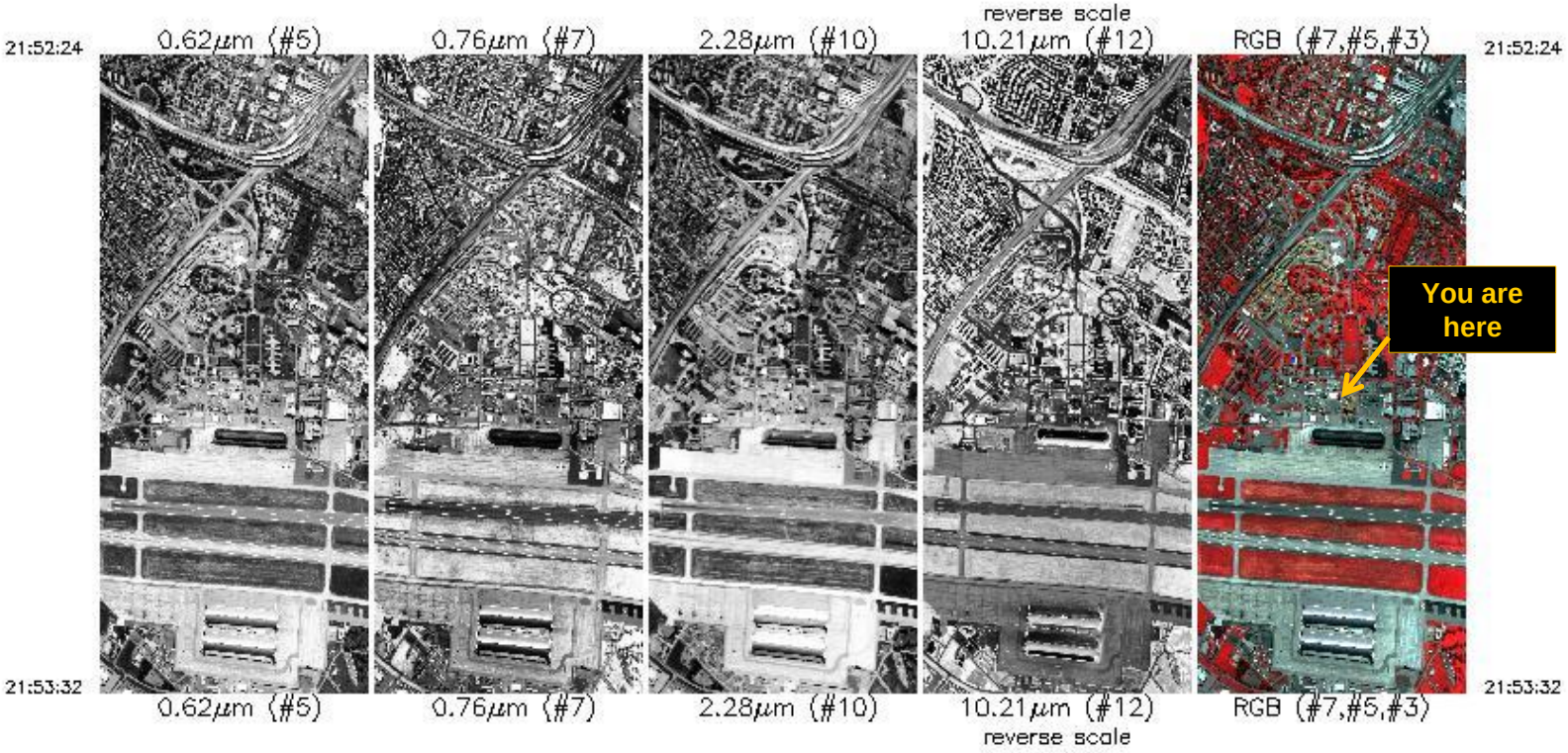
1. **LINUX-based flight software used on E-MAS, MASTER**
2. **New Motor-Mirror-Encoder design**
3. **New Motor and BB Controllers**
4. **Real-time interface to POS-AV**

Sensor Network Hardware Development





AMS Airborne Simulator Browse Imagery
Sensor Validation Campaign – 18 Apr 2006
Moffett Field, CA
Flight #06–004–01 Track #2



Upper Left Lat, Lon = 37.4°, −122.1°
Lower Right Lat, Lon = 37.4°, −122.0°
Aircraft Heading = 67.1°
Solar Zenith = 35.5°
GPS Altitude = 778. m (MSL)

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