New Mission, New Orbit, No Problem—Applying the Responsive Space Capability to Meet the ORS-6 Mission

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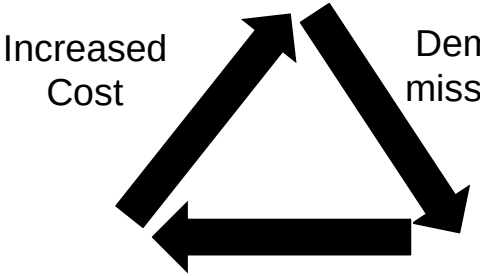
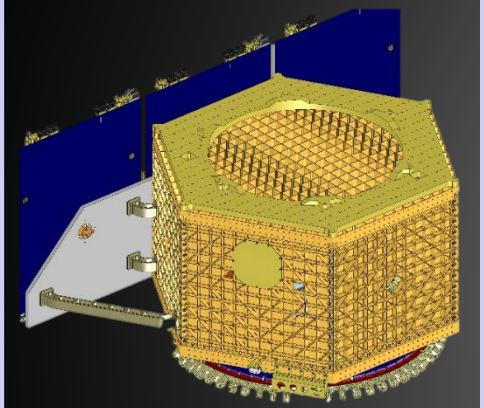
How Can We Decrease Cost of Operational Missions?



- The government is plagued by consistent cost and schedule overruns of high $ missions

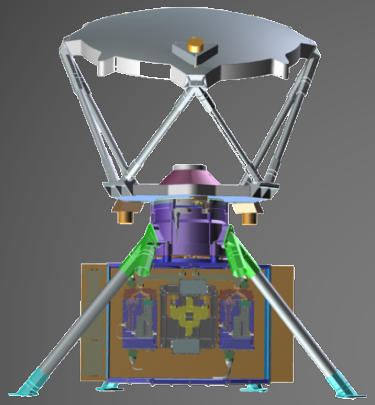
- The Air Force weather satellites are no exception:
  - NPOESS
    - Canceled 2010 due to cost and schedule overruns
  - DWSS
    - Canceled in 2011 after $153M investment
  - DMSP-F20
    - High risk of cancellation after $500M investment
- Weather System Follow-On currently budgeted at $800M

ORS-6 Mission: A Low Cost Demonstration to Positively Impact the Weather System Follow-On



Modular Space Vehicle (MSV)

- ORS-2 Bus
- Delivered 2013
- Reconfigure for ORS-6
- Uses SPA architecture
- Designed for efficient adaptation to new payloads and orbits



Compact Ocean Wind Vector Radiometer (COWVR)

- Completed 2015
- Reconfigure for ORS-6
- High measurement accuracy, lower power and weight

Multi-Mission Satellite Operations Center (MMSOC)

- Completed 2015
- Significant investment
- On-ramp to EGS

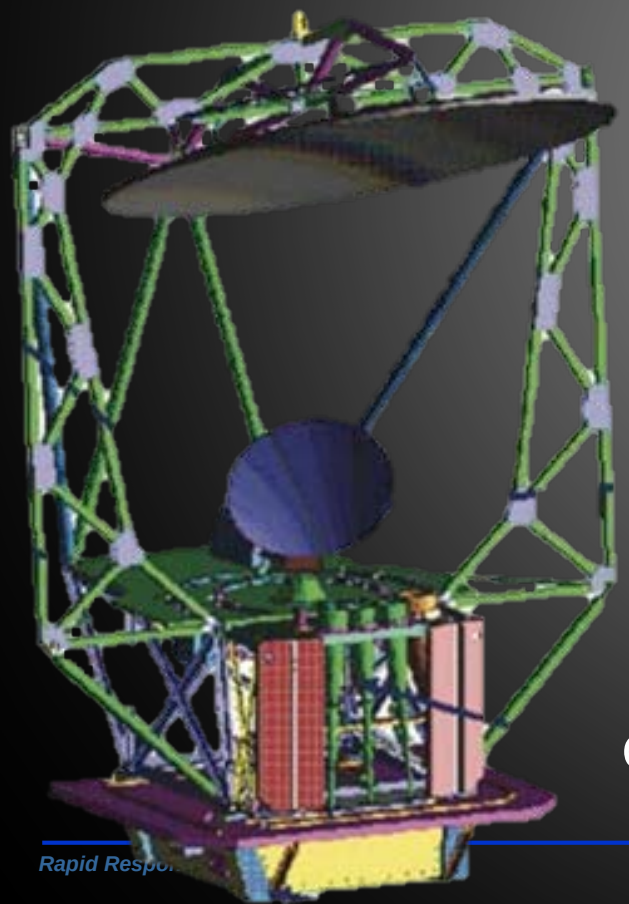
Falcon 9 Launch

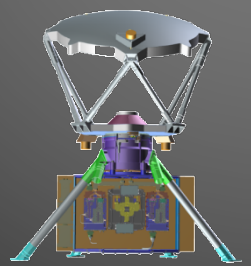
- Brokered rideshare
- Fall 2017 launch date
- Integrated payload stack
- ORS-6 is a secondary payload
- ~600km, sun-sync

Technology Demonstration Mission with Potential for Residual Capability

COWVR: High Performance, Low Cost, Power and Mass

Item	WindSat	COWVR
Number of Feeds	11	1
Receivers	22	2
Mass [kg]	330	<70
Power [W]	350	<100
Spun Momentum [N-m-s]	190	<10



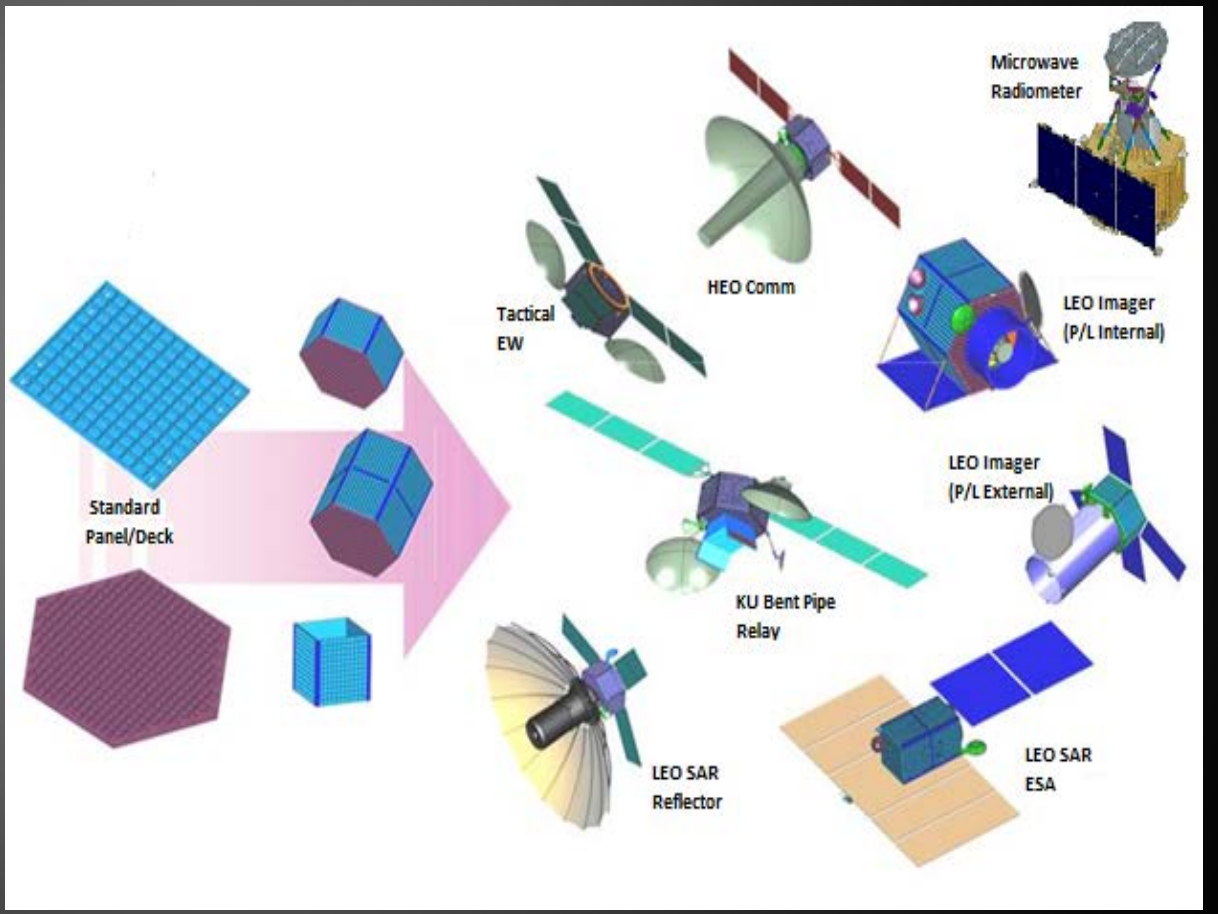


- **Unlike current wind vector radiometers, COWVR has an unobstructed 360° field of view**
- **This improves accuracy of wind vector models**
- **The internal calibration sources also make COWVR more adaptable to changes in orbit**
- **Measures wind vectors at comparable accuracy and resolution to operational satellites at a fraction of the cost.**

COWVR to WindSat size comparison

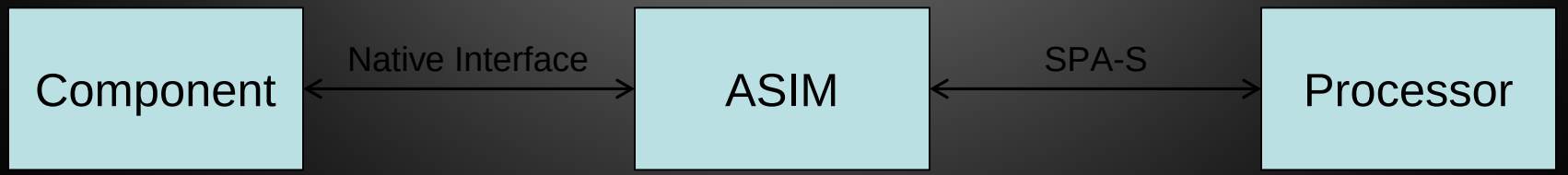
ORS-6 Bus: Modular Space Vehicle (MSV)

- **The MSV architecture is designed to be like Legos:**
  - **Easily reconfigurable**
  - **Modular components**
  - **Common building blocks that can be assembled in many ways depending on the mission**
  - **Grid pattern enables movement of any component to within 5 linear cm**



SPA: Space Plug and Play Architecture

- **Just like the bus hardware the bus software is also modular**
  - **SPA standardizes communication between all components**
  - **Connects all components to a universal network**
  - **SPA compatible components can be developed independent of a vehicles' architecture and without having access to the actual vehicle**
  - **Software is isolated on each component, enabling ease of parallel work**
  - **Middleware code is open source and available from Space Dynamics Lab**
  - **Common harnessing, power delivery, and data exchange**



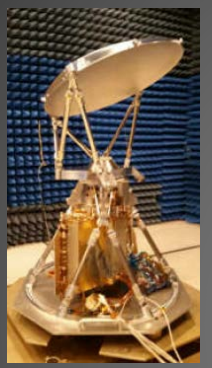
Changes from ORS-2 to ORS-6

Mission

- **18-month design lifetime with 3-year goal**
- **Sun-synch orbit at ~600 km**
- **Falcon 9 Launch Vehicle**

Payload

- **On-orbit demonstration of COWVR technology for ocean vector wind measurement**
- **Mass <70 kg**
- **OAP Power <100 W**
- **Data Rate > 50 kbps**



Payload Interface

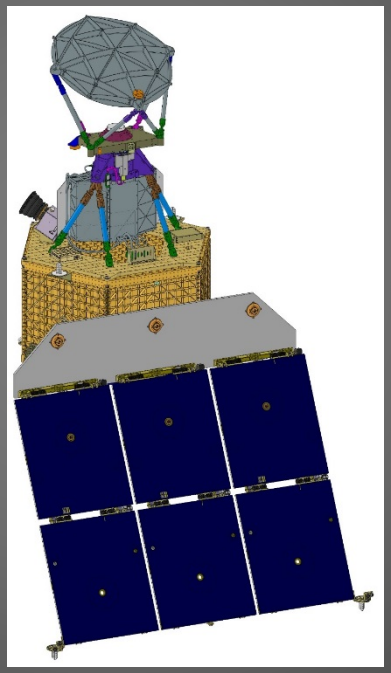
- **Remove CDL**
- **Add Payload Interface Unit (PIU) consisting of ASIM, 16 GB data storage, and bus-to-payload interfaces**
- **Create Payload xTEDS with commands / telemetry messages for SPA integration**

Flight Software

- SPA compatible infrastructure including Agent Manager, Mission Database, multiple agents, and controllers
- ASIM software for component SPA interfaces
- Development of xTEDS
- **Modify Payload Agent for COWVR CONOPS**
- **Update ADCS FSW**

Structure

- All aluminum primary structure
- Hexagonal prism structure
- 71.1 cm high x 112.0 cm flat-to-flat
- **Add solar panel support structure**
- **Add COWVR interface ring**



Thermal Control

- Cold-biased system with thermostat-controlled heaters
- Thermally isolated payload deck
- Thermal control interface adapters (TCIAs) used to mount non-SPA compliant components

Electrical Power

- Direct energy transfer system
- Six ORS-2 solar array panels
- **Single planar wing**
- Two 24 A-hr batteries

C&DH

- Receives, processes, and distributes commands and memory loads for the spacecraft and payload
- Collects and distributes spacecraft and payload telemetry
- Includes SPA-compatible hardware including SPA router and ASIMs

TT&C

- **AFSCN SGLS/USB Software Defined Radio (SDR)**
- **Type 1 Approved AES-256 GNOME/Gryphon**
- **Relocate omni antennas**
- **Add - Comm ASIM**

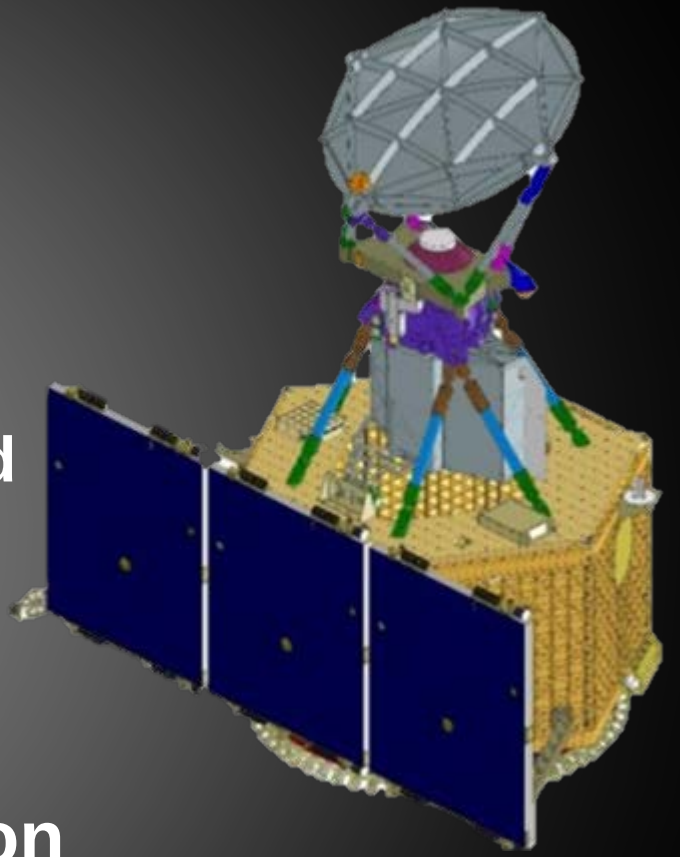
ADCS

- Zero momentum 3-axis control system
- (1) Type B RWA, (2) Type E RWAs,(3) MTR, Mag, IRU, GPS and ST
- **Relocate Star Tracker to payload deck**

Changes from MSV SAR identified in blue bold text

Bus Modifications for the New Mission

- **Payload Interface Unit**
  - Power and data interface, translates payload to SPA
- **Software Defined Radio**
  - ORS-2 radio was de-scoped before bus completion
- **Radio ASIM**
  - Translates radio to SPA
- **Solar array reconfiguration**
  - Update for sun-sync orbit
- **Update ADCS flight software**
  - Delivered FSW was unstable



Successes and Lessons Learned from the MSV Architecture Going from ORS-2 to ORS-6

Successes

- Easy repositioning of the star tracker
- Easily move solar array location
- Modular software allowed processor utilization to be shared among components
- Early testing of bus to identify issues prior to AI&T

In Between

- ADCS software was easily isolated to enable rewriting. However the replacement software is 3rd party, proprietary, and not SPA compliant

Obstacles

- Slow processor speed required streamlining software on many components. Streamlined software is 3rd party and proprietary.

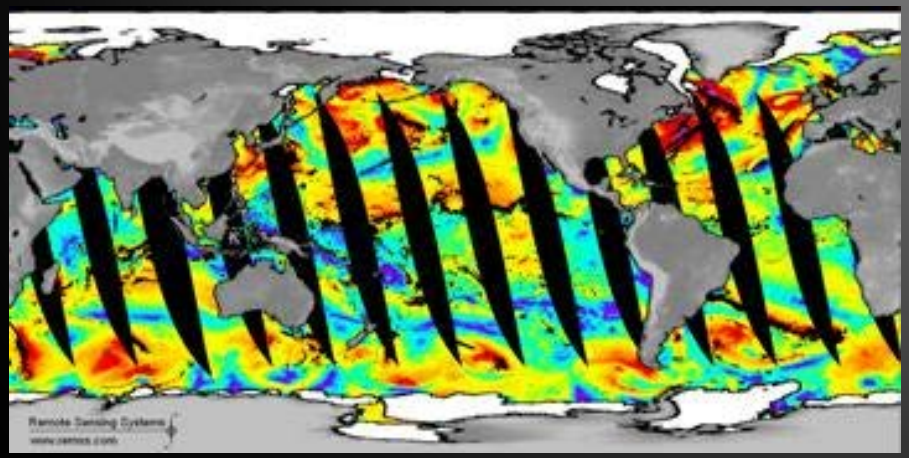
Commercial Ride Share: A Cost Savings Approach

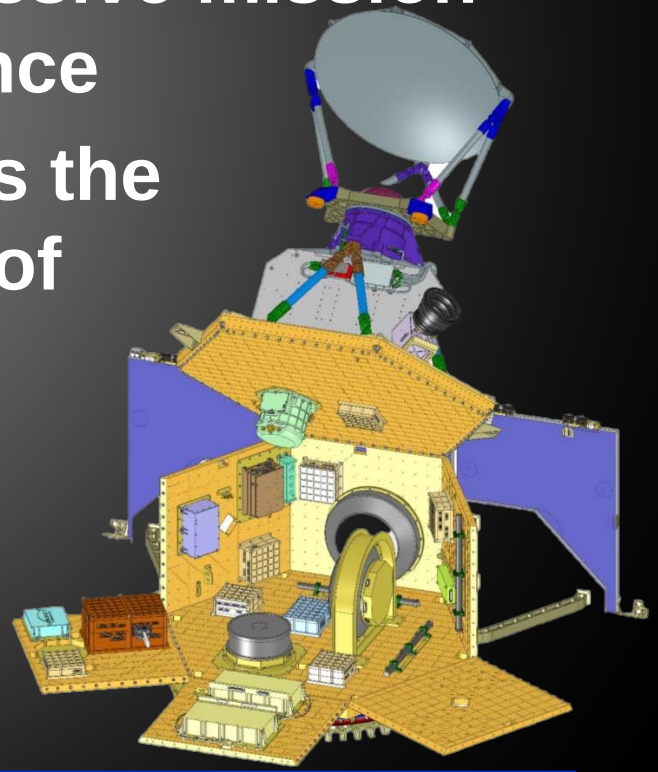
- Among the first pursued by the Air Force for this class of mission
- Saved between 25-50% on launch costs
- Providing faster access to space

- However, because we are not the lead payload for launch:
  - We do not get ideal orbit
  - We must deliver on time

Summary: How to Build an Operational-Like Satellite for an Order of Magnitude Less Cost

- Explore new payload technology
- Leverage existing resources
- Use modular MSV hardware and modular SPA software
- Pursue commercial ride share for lower launch cost
- Avoid the temptation of excessive mission assurance
- Better is the enemy of good enough





Acronyms

- **ADCS** Attitude Determination and Control System
- **ASIM** Applique Sensor Interface Module
- **CDL** Common Data Link
- **C&DH** Communications and Data Handling
- **DMSP** Defense Meteorological Satellite Program
- **DWSS** Defense Weather Satellite System
- **EGS** Enterprise Ground System
- **FSW** Flight Software
- **IRU** Inertial Reference Unit
- **MTR** Magnetic Torque Rod
- **NPOESS** National Polar-Orbiting Operational Environmental Satellite System
- **OAP** Orbit Average Power
- **ORS** Operational Responsive Space Office
- **RWA** Reaction Wheel Assembly
- **SMC** Space and Missile Systems Center
- **ST** Star Tracker
- **TT&C** Telemetry, Tracking and Communications
- **xTEDS** Extensible Transducer Electronic Data Sheets