SOFIA Water Vapor Monitor Status and Calibration 10/20/14

Thomas L. Roellig
NASA ARC

Agenda

- **Current Status of the WVM**
- **WVM Calibration Requirements**
- **WVM Calibration Plans**

WVM Operations

- WVM observes the 183.3 GHz water emission line. This line is optically thin in the stratosphere so it provides a measure of the integrated water vapor along a line of sight at an ~40° elevation angle.

- WVM operates largely autonomously – the MD sends a few power-up and power down commands

- WVM subscribes to MCCS engineering data such as the aircraft role and pitch angles, outside air temperature, outside air pressure.

- Reports the water vapor to the zenith every 15 seconds to the MCCS, and records information to the Archiver every 1 second. MCCS calculates the water vapor along the TA LOS (algorithm needs fixing)

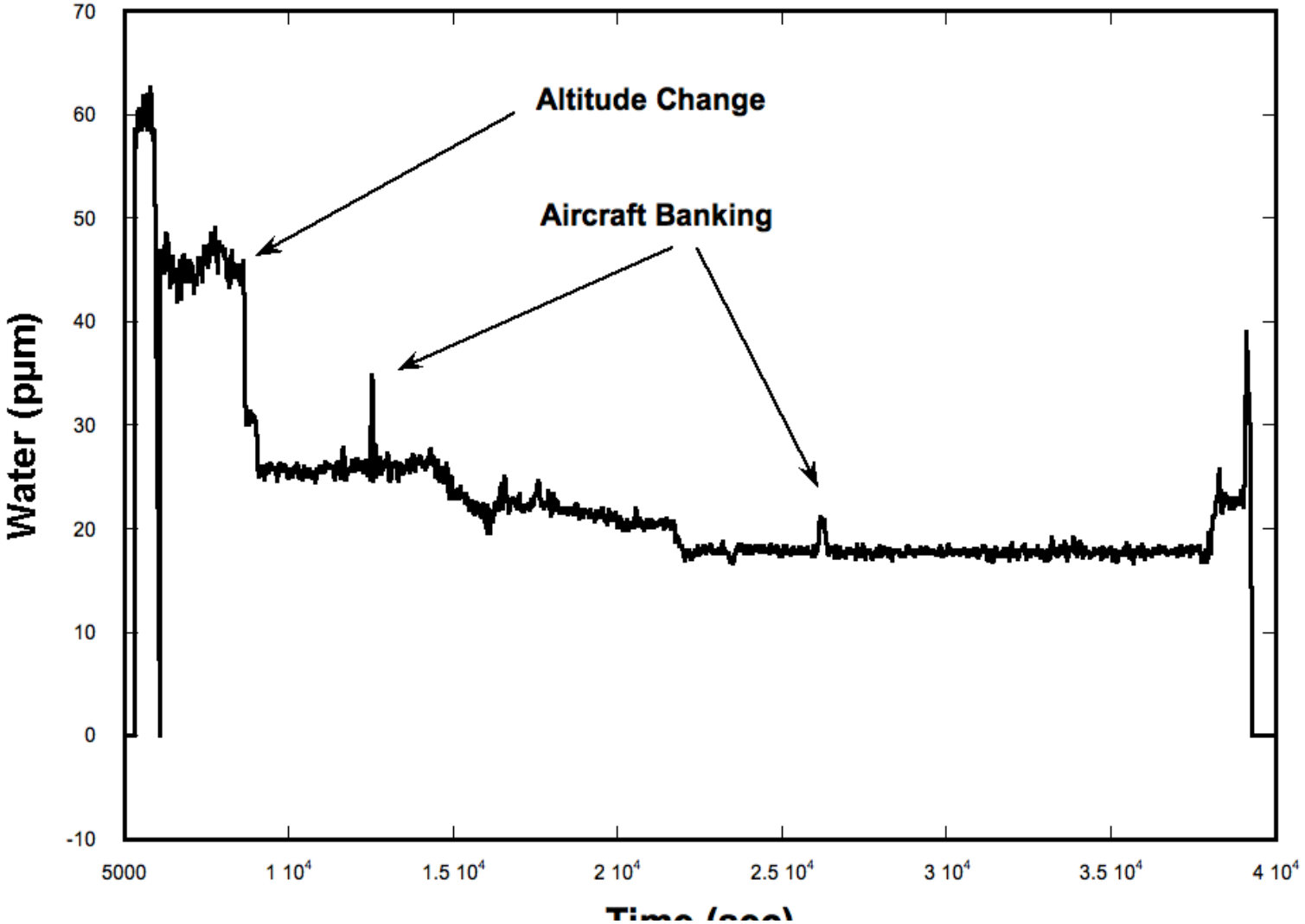
WVM Hardware Current Status

- All the WVM hardware has been removed from the aircraft for the HMV
- RHD/IFC Flight Unit #1 and the Qual RHD/IFC are in the ARC labs
- Flight Unit #2 hardware components (boards, sub assemblies, etc) are constructed, but still need final assembly
- Stepper motor controllers used for internal calibration have proven to be unreliable, need to be replaced with new design
- Many parts have become obsolete, but there is a stock of spares on hand

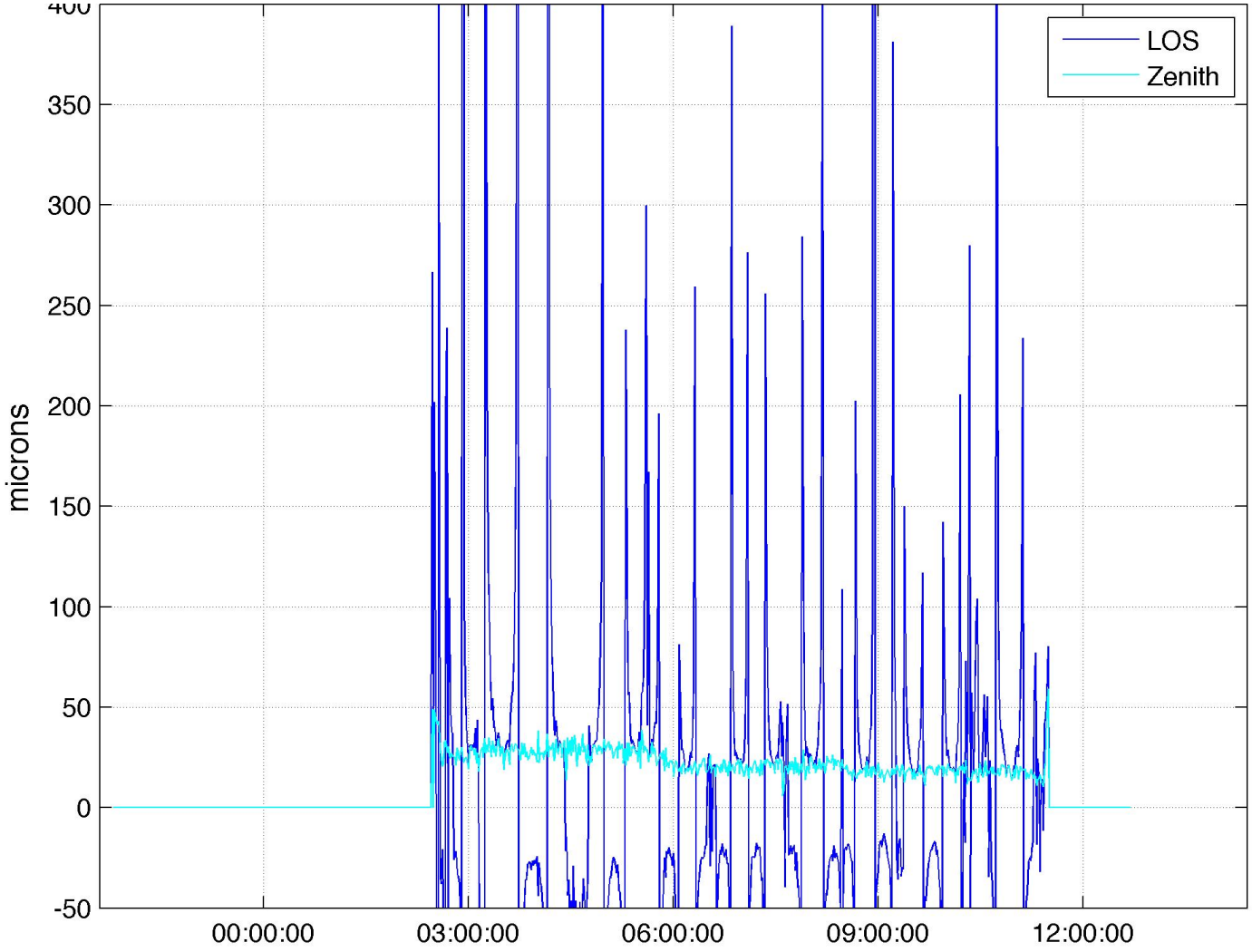
WVM Software Current Status

- The current WVM software is functional, but needs revision to:
  - Meet WV accuracy performance requirements. Noise in receiver meets requirements, but need to rework how internal calibration is handled
  - Meet time to repair requirements. Need to add software switching so that new configuration files are not needed when WVM flight units 1 and 2 are swapped
  - Addition S/W extension work planned – such as better error messages, updated MCCS WVM GUI, perhaps even change from Class IV to Class III

WVM Sample Flight Data



MCCS LOS Problem



WVM Data Use

- A) In real-time during flight to make SI configurations decisions (needed: absolute WV levels, low-accuracy, low sample rate)
- B) Post-flight for IR flux corrections (needed: absolute WV levels, high-accuracy, low sample rate, good understanding of how water vapor affects the IR flux detected in each instrument)
- C) Post-flight for reducing noise in transit observations (needed: relative WV levels, high relative accuracy, high sample rate)

Do We Need Absolute Calibration?

- Current top-level requirement;" The Water Vapor Monitor subsystem shall output data of precipitable water vapor, in microns, to the zenith, an accuracy of ±1 micron (3-sigma) under these conditions: 1. Measure once per minute. 2. Precipitable water vapor level to the zenith is between 4 and 20 microns. 3. Corresponding to flight altitudes of 35,500 to 46,000 feet in a Standard Atmosphere. 4. An aircraft roll angle is between ±5°."

- There are historical reasons that this data wasrequired that are not related to our current science needs

- This data is only useful we understand how to apply it in calculating the effects of water vapor on our SI data.

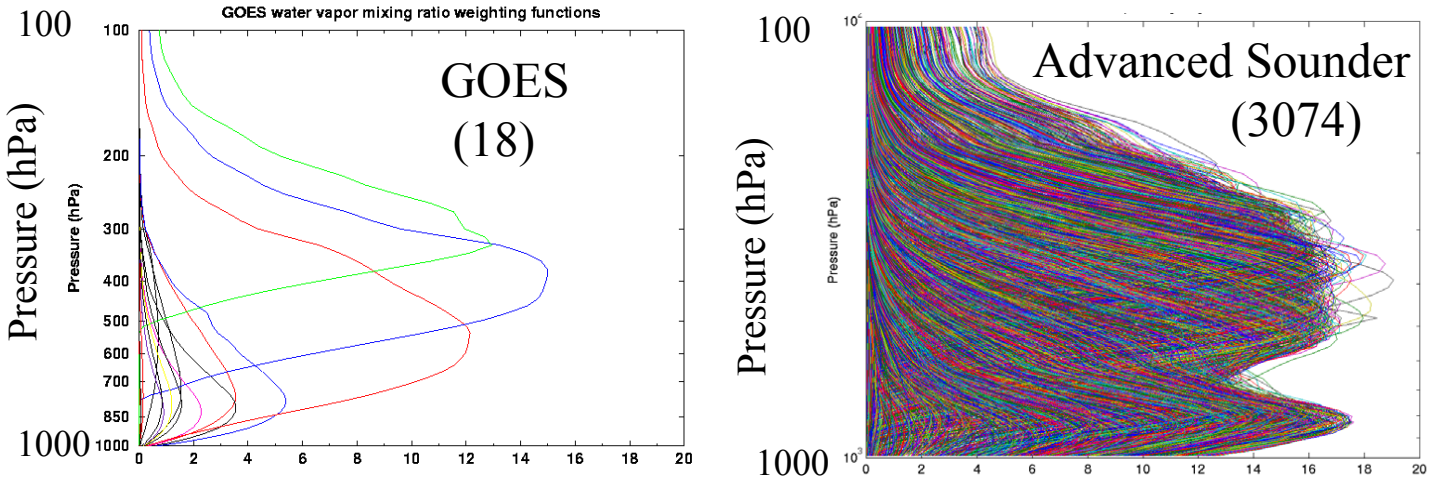
- To absolutely flight calibrate the WVM we need to know "what is truth" when we are running the WVM. Getting this truth is an issue.

Getting Water Vapor Truth Data

- Satellites have their issues
  - Nadir-looking sounders like the GEO-Vs have poor vertical resolution, but do provide continuous geosynchronous coverage
  - Limb scanners like on the one on AURA are a bit better (~3km) but they are in LEO and in general may not be at the same place and time as SOFIA is flying.
  - There is x2 discrepancies between the data from different satellite systems

- Balloons sample water vapor and go up to 100,000 ft.
  - However standard meteorological balloon packages have very poor accuracy above the tropopause.
  - The NCAR upper atmosphere research group in Boulder send up a balloon one a month there with better instrumentation, but that is just one place an one time, and in the day too.

GOES-V Weighting Functions



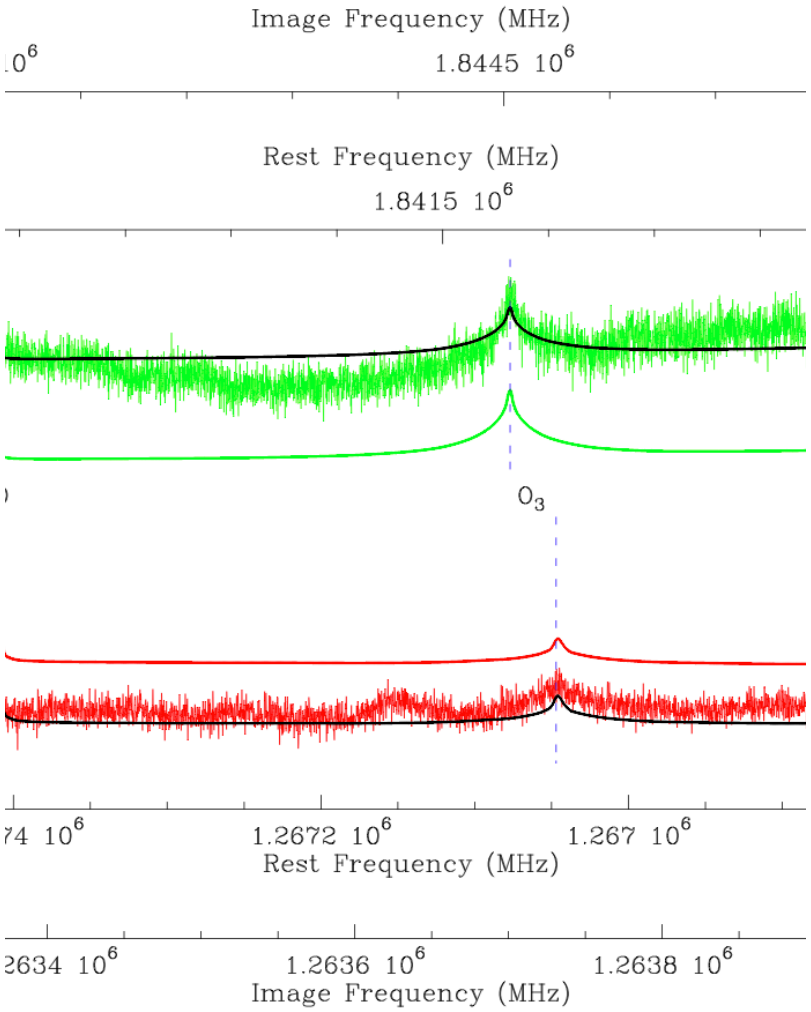
Moisture Weighting Functions

High spectral resolution advanced sounder will have more and sharper weighting functions compared to current GOES sounder. Retrievals will have better vertical resolution.

Getting Water Vapor Truth Data (2)

- LIDAR
  - Works at night by Raman excitation of H2O
  - Good vertical resolution (~300m)
  - One is operated by JPL at nearby Table Mountain, but it only goes up to ~49,000 ft.
  - One in the works for EAFB that goes up to 80 km (262,000 ft., but may or may not actually measure water vapor to that level (supports a DoD dark program and it is a bit hard to get information)
- SOFIA Science Instruments
  - Spectrometers can measure shape and depth of water lines
  - However still need a model to extract absolute water from these measurements
  - CGS on KAO found that different lines give different water levels

And What Would We Do With Absolute Measurements Anyway?



- GREAT best fit to data
  - Green is L2
  - Red is L1
  - Black line 35 μm pwv in L2
  - Red line 12.3 μm pwv in L1
  - Red and green lines are best common fit

Suggested WVM Calibration Plan

- Verify WVM S/N requirement in V&V flight series (we currently have 30 minutes in first flight)
- Remove (or relax) the WVM absolute requirement (requires Program-level concurrence to changes this requirement)
- Move calculation of LOS WV into ground data processing (need to fix up ICDs and data reported by MCCS)
- Keep current with NCAR high-altitude balloon launches and try to do one close to the time that SOFIA is flying nearby (NCAR is willing to adjust launch dates by ± a few days)
- Talk with Ed Teets at AFRC about when the EAFB LIDAR system may be ready
- Use H2O line measurements from GREAT and EXES
- And most of all, laboriously build up a database of the relationship between the WVM measurements of the 183.3 GHz line and the received signals from all the SIs (with each mode, filter, grism) as they look at calibration objects

Backup Slides

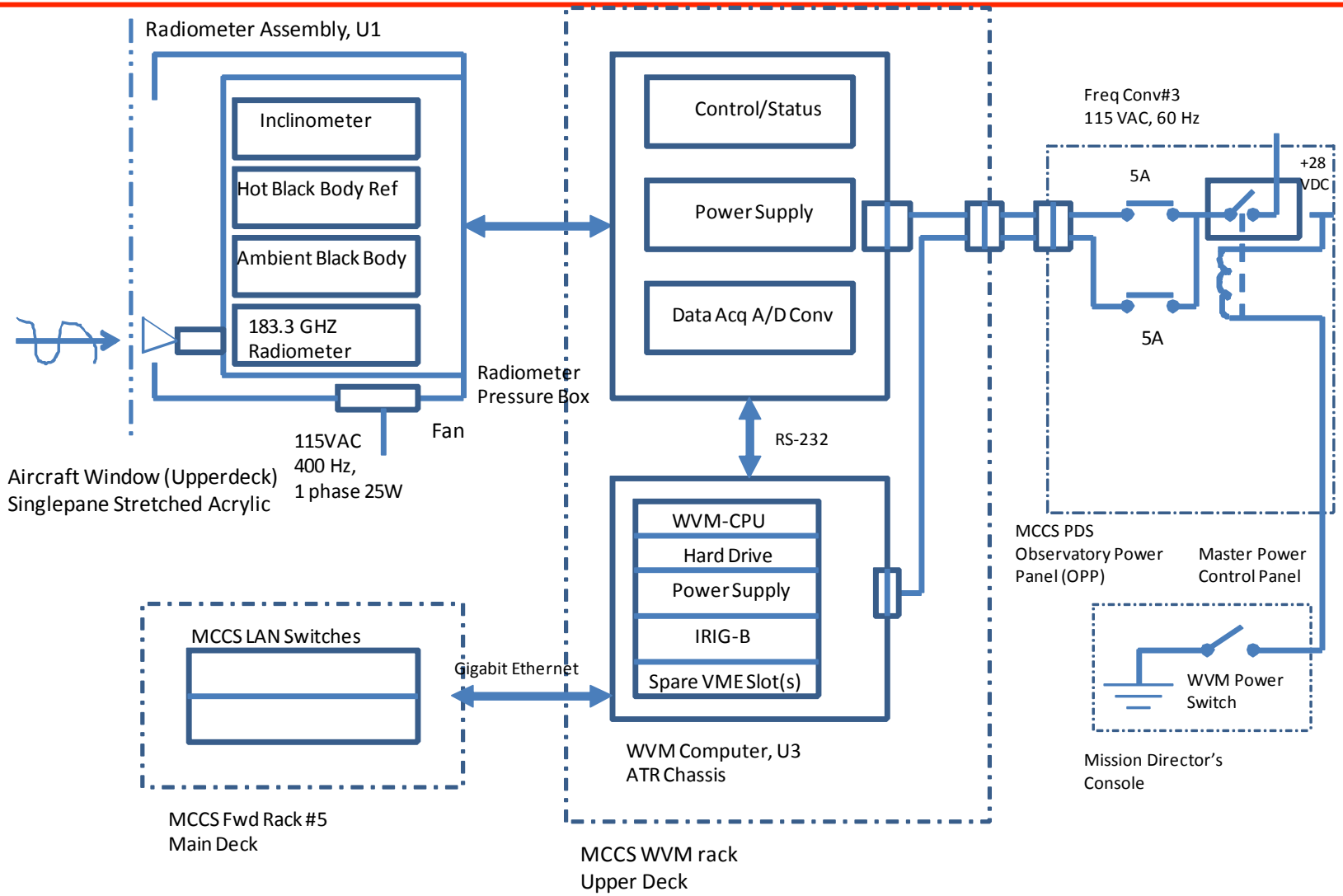
Background

- WVM hardware consists of 3 components
  - Radiometer head (RHD)
  - IF Converter Box (IFC)
  - WVM CPU (WVMCPU)

- Plan is to have two interchangeable sets of flight RHD and IFC pairs, plus the hardware qual units that will live in the HIL and can be used as an second emergency spare

- WVM Software has two components
  - WVM Data Acquisition Software (DAS) – resides in IFC and performs low-level functions
  - WVM Control Section Software (CSS) – resides in WVM CPU and calculates WV overburden and communicates with the MCCS

WVM Overview



WVM Hardware in Aircraft