Statement Of Work

1. Overview

The NASA Goddard Space Flight Center (GSFC) Mobile Observatory, SMART (Surface-sensing Measurements for Atmospheric Radiative Transfer) – COMMIT (Chemical, Optical, & Microphysical Measurements of In-situ Troposphere), has been operating in field experiments (http://smart-commit.gsfc.nasa.gov) for nearly a decade to support satellite validation missions. To gain a better understanding of the effect of clouds on atmospheric radiative processes, three-dimensional cloud structure data are required and an addition of ACHIEVE (Aerosol-Cloud-Humidity Interactions Exploring & Validating Enterprise) facility to the SMART-COMMIT mobile observatory is currently underway.

This specification outlines the minimum requirements necessary to meet GSFC's science goals with the ACHIEVE Radar (ACHIEVER). The ACHIEVER is a W-band, dual-polarization Doppler radar mounted on an elevation-over-azimuth antenna positioner, which will be set up to operate in various modes by a local or remote operator. When operating, the ACHIEVER shall record data in hourly files that are pulled via ftp/sftp by the GSFC site data system. Figure 1 depicts the preferred method of mounting ACHIEVER above the ACHIEVE trailer. An economical and sturdy radome, with low loss at ACHIEVER frequencies, should be applied to the radar and positioner (*cf.* Fig. 1) to prevent moisture, ice, and snow from collecting on the antenna, as well as hail damage.

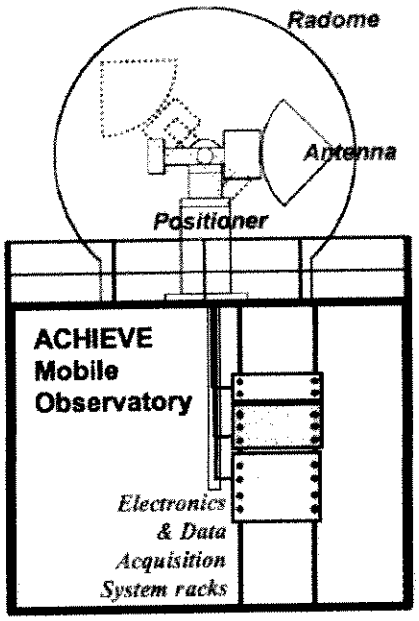

Figure 1. A cross-section view of ACHIEVER installation for field deployment

2. System Requirements

- The ACHIEVER data acquisition system and electronics not required to be on the antenna positioner shall be housed in a thermoplastic rack case such as those made by Hardigg Industries. ACHIEVE shall provide the shelter that these rack(s) shall be installed in.

- The ACHIEVER shall be packaged so that subsystems (with the exception of the antenna positioner) are movable by two people. Components that are mounted in an instrument shelter shall fit through standard 30-inch doorways.

- To the maximum extent possible, all components and major subsystems shall be commercial-off-the-shelf (COTS).

3. Radar Requirements

- Frequency shall be 94.0 GHz.
- PRF shall be adjustable from 1 kHz to 20 kHz.
- Pulse width shall be adjustable from 50 ns to 300 ns in 50 ns steps.
- Antenna diameter shall be approximately 1 meter.
- Antenna cross-polarization isolation shall be at least 27 dB
- Digital transceiver shall allow for user selected modulation methods to include:
  — simple pulse modulation,
  — pulse code modulation,
  — pulse FM chirp modulation (both linear and nonlinear).
- ACHIEVER shall be a dual polarization radar, transmitting in linear horizontal polarization and receiving linear co-polarization and cross-polarization, which is accomplished with two separate receiver channels.
- Transmitter shall have an operational life expectancy of at least 20,000 hours when operating 24 hours/day and 7 days/week.

4. Data Acquisition Requirements

- *Radar calibration:* In this mode, the system shall prompt the operator (or retrieve from a file in remote mode) for the required actions (i.e. signal injection, antenna pointing, etc.) required to calibrate the radar. The system shall step through the attenuator and record the radar return signal at a fixed range gate. The calibration data shall be written to disk with a time stamped file header.
- *Data processing:* To alleviate processor load, it is allowable to process the raw data every hour by a separate computer, if necessary. During processing, the two-way atmospheric loss shall be assumed to be unity. The radar system losses shall be a parameter that is entered by the user and represents the loss from the antenna feed to the point that a RF signal is injected for calibration.
- *Data acquisition:* This mode shall collect data. The data shall be time tagged and written to disk as it is taken.
- *Data range correction:* This is a post trial data analysis mode that shall provide range correction to the raw data.
- *Data calibration:* This mode shall process the range corrected data with the calibration data to provide the final output data files. The reflectivity data shall be converted to dBZ units.
- *Doppler moments:* The radar data system shall use FFT techniques to estimate the

first three Doppler moments, i.e. reflectivity, radial Doppler velocity, and spectral width. The FFT size shall be user selectable at 128, 256, 512, and 1024 points.

- *Spectra image rejection:* The digital signal processing algorithms shall be optimized such that spectral images are at least 30 dB down.
- *Processor efficiency:* The receiver/data acquisition system shall have processor efficiency greater than 95%. This is defined as the fraction of radar pulses/range gates that are actually processed.
- *I/Q data:* The data acquisition system shall have a selectable option to record raw I/Q data.
- *Data file generation:* All data files shall be hourly files. They shall be placed in a directory that shall allow them to be transferred via Internet by ftp/sftp. The user shall be able to select the file collection directory so that data can be written to a large capacity external disk in the event the radar is operating in a stand-alone configuration.
- *Data storage:* The data acquisition system shall have enough disk storage to store
  - two weeks of moments data,
  - four days of spectral data,
  - one day of I/Q data.
- *Output file format:* The following data files shall be generated at a minimum
  - moments data files,
  - spectra/moments data files,
  - system health and monitoring data files.
- *Moments data minimum requirements:* The following variables shall be stored
  - Base time (time measurement began),
  - Offset from base time (seconds),
  - Number of FFT points used in moment estimation,
  - Range – distance for radar range gate measured at the center of the range gate,
  - Modulation method,
  - Pulse width,
  - Pulse repetition frequency,
  - Transmit power at transmitter output,
  - Transmit power at antenna feed,
  - Ambient outside temperature,
  - Transmitter temperature,
  - Antenna top temperature,
  - Antenna bottom temperature,
  - Antenna humidity,
  - Electronics rack temperature,
  - Chiller supply temperature (if used),
  - Chiller return temperature (if used),
  - Calibration data,
  - Reflectivity,
  - Polarization,
  - Mean Doppler velocity,
  - Spectral width,

- Noise level for range gate,
- Signal to noise ratio for range gate,
- Antenna positioner elevation as a function of time,
- Antenna positioner azimuth as a function of time,
- Latitude,
- Longitude,
- Altitude.

- *Spectra/Moments data file minimum requirements:*
  - Requirements are the same as the Moments file requirements with the addition of the radar spectra as a function of range and time.
  - Operator shall be able to select a different directory/folder for storage of Spectra/Moments data. This shall be used at installations where there is not have enough Internet bandwidth to transfer spectra data (in which case these data shall be written to an external disk).

- *System Monitoring and Health data file minimum requirements:*
  - Shall be daily files with ten minute mean, maximum, minimum, and standard deviation of the following variables: Transmit power at transmitter output,
    Transmit power at antenna feed,
    Ambient outside temperature,
    Transmitter temperature,
    Antenna top temperature,
    Antenna bottom temperature,
    Antenna humidity,
    Electronics rack temperature,
    Chiller supply temperature (if used),
    Chiller return temperature (if used),
    Key voltages,
    Disk usage.
  - This file shall be stored in two locations: The same directory as the Moments data file so that it can be collected by the GSFC site data system; and An Archive directory on the data acquisition system that holds the last 90 days of the System Monitoring and Health data.
  - The radar application software shall allow for the provision to e-mail a list of addresses in the event any of the monitored conditions is in an alarm condition.

- *Operating System:* The data system's operating system shall be one that is currently supported or shall be in the foreseeable future. Either Linux or Microsoft Windows are acceptable.

5. Operator Interface Requirements

- *Local control:* The system shall be designed so that a person using the data acquisition/control computer may operate it.
- *Remote control:* The system shall be operable by remote control via an Ethernet network link. All operating functions shall be made available while operating in remote mode.
- *Selectable radar parameters:* At a minimum, the operator shall be able to graphi-

cally select the following radar parameters in local mode. In remote mode, the following radar parameters shall be selected by Ethernet file transfer protocol (ftp) to the radar system computer. The system shall maintain a time stamped log file to identify whenever any of these parameters has been changed.

- Beginning range: This shall be the beginning range in which data acquisitions take place in meters.
- Ending range: This shall be the ending range in which data acquisitions take place in meters.
- Range resolution: The range gate size in meters.
- Integration time - The time each range gate is averaged. Could also be listed as the number of range gates integrated (seconds or number of pulses).

- *Graphical display:* The system shall provide 3-D graphical data of
  - raw data that is not range corrected or calibrated (relative power vs. time),
  - range corrected data that has not been calibrated (range corrected relative power vs. time),
  - range corrected, calibrated data (dBZ vs. time),
  - velocity vs. time.
- At a minimum, the raw data that is neither range corrected nor calibrated shall be displayed in real time while data acquisition is taking place.

6. Scanning Requirements

- The ACHIEVER shall be mounted on an elevation-over-azimuth positioner.
- The positioner shall be able to scan at least 36°/sec with a position accuracy of at least 0.1° and peak acceleration of 36°/sec^2.
- To the maximum extent possible, rotary joints/connections shall be used to connect the radar to its data acquisition system.
- The centerline of the antenna when horizontal shall be 2 meters from the ACHIEVE trailer rooftop.
- An Axis 221 Network Camera in an environmental enclosure shall be boresight mounted between the two antennas if an enclosing radome is not feasible.
- The system shall incorporate the following scanning techniques:
  - *Range Height Indication (RHI),* horizon to horizon capable where operator enters: Starting elevation/azimuth
    Ending elevation (ending azimuth same 180 degrees out from starting azimuth)
    Number of sweeps or continuous scan
    Sweep speed
  - *Plan Position Indication (PPI),* single revolution and then retrace where operator enters: Starting elevation
    Ending elevation
    Elevation increment angle
    Number of sweeps or continuous scan
    Sweep speed
  - *Sector/Raster scans*, the scan is defined by:
    Starting elevation/azimuth

Ending elevation/azimuth
Elevation increment angle
Number of scans or continuous
Sweep speed

— *Fixed staring mode,* fixed elevation and azimuth with the ability to collect spectra data. This will most often be used for pointing at zenith. It will also be used for calibration to a fixed corner reflector. Operator enters:

Elevation
Azimuth
Dwell time or continuous staring

— *Sequencing staring mode,* fixed elevation and azimuth with the ability to collect spectra data. This will most often be used for pointing at zenith. It will also be used for calibration to a fixed corner reflector. The system shall have the capability to store at least 5 fixed coordinates and step through these at a set dwell time. Operator enters:

Elevation
Azimuth
Dwell time or continuous staring.

7. Operational Requirements

- A 45° polarizer shall be added between the OMT and antennas.
- It is anticipated that some components of the ACHIEVER will be located on the positioner while some components will be located indoors. Therefore, the umbilical between the positioner and indoor components shall be at least 5 meters long.
- Control and parameter input shall be made via a GUI that input can be password protected or through a configuration file. Either way, the configuration history shall be archived.
- The GUI software shall display the current position of the positioner, the scanning mode it is in, and its scan speed.
- ACHIEVER shall have a "KILL" switch both the positioner and indoor control rack to immediately stop scanning (see message from Orbit; power switch on base, we can add a kill switch outdoors near the positioner).
- ACHIEVER shall have a "STOP" button on the client control software to immediately stop scanning.
- ACHIEVER shall have an external calibration mode allows the pointing of the radar at a known radar cross-section calibration target. The ACHIEVER software shall automatically calibrate itself from this target.
- ACHIEVER shall run off 120/230 VAC, 50/60 Hz.
- A pole-mounted corner reflector shall be included with the ACHIEVER for absolute radar calibration. A trihedral corner reflector of ACHIEVER cross-section shall be included and its relative location to ACHIEVE observatory shall be determined.

8. Environmental Requirements

NASA/GSFC will potentially deploy the ACHIEVER with the SMART-COMMIT-ACHIEVE Mobile Observatory in locations all over the world. Thus, the ACHIEVER shall be designed to operate in various climate regimes.

- *Temperature:* from -40 °C to 60 °C for outside components, 20 °C to 35 °C for indoors components
- *Relative humidity:* from 0% to 100% humidity
- *Radome:* The interior of the radome shall be heated (or the air dried) to prevent condensation on the interior of the radome or the antenna.

9. Mechanical Requirements

- *Weight:* prior to assembly, no single component of the radar and electronics (with the exception of the positioner and radome, if used) shall weigh more than 90 kg.
- *Size:* when disassembled and packed for shipment, all components shall fit in a single 8' x 8' x 20' ISO container.
- *Packaging:* Individual components shall be packed in thermoplastic cases or reusable wood crates as the size of each dictates.
- *Mounting:* the ACHIEVER and its supporting infrastructure shall be designed to withstand sustained winds of 35 m/s and gusts to 45 m/s.

10. Electrical Requirements

- *Voltage:* 115/230 VAC single phase
- *Frequency:* 48 – 62 Hz
- *Uninterruptible Power Supply (UPS):* 20 minutes for all components other than antenna positioner. The UPS shall have Internet connectivity.
- *Internet Power Switch:* The ACHIEVER shall include an Internet accessible power switch (such as the APC Switch Rack PDU) that will allow the power cycling of all major components without going through any of the ACHIEVER data systems or network hubs/switches.

11. Documentation

Because ACHIEVER will be deployed in very remote locations all over the world, accurate and detailed system documentation is required.

- Schematics/Assembly Drawings
- As-build schematics and assembly drawings shall be provided with delivery of the system. Wiring diagrams shall also be provided.
- Software Documentation
- Source code (hardcopy and media) shall be provided along with all appropriate make, build, link, etc files. A software maintenance manual shall also be provided that shows the organization of the software modules, data flow, file structure, interfaces, etc.

- An Operations & Maintenance (O&M) Manual shall be delivered with the system. The O&M manual shall have a section that details the concept of operation. An appendix to this manual shall include manufacturer's data sheets for all electronic components in the system.

12. Deliverables

- 1 ACHIEVER
- Software Manual
- Operations/Maintenance Manual
- Installation of ACHIEVER at NASA/GSFC
- Operations training at NASA/GSFC.