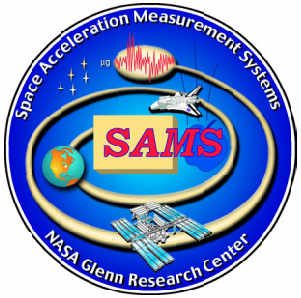
Section 6

Space Acceleration Measurement Systems (SAMS)



William M. Foster II

Agenda

- Purpose, Organization, & Requirements
- Acceleration Measurement Systems
  - History
  - Present Systems
  - Future Systems
- Examples of Deployment
- Customers - How to request SAMS
- Conclusion

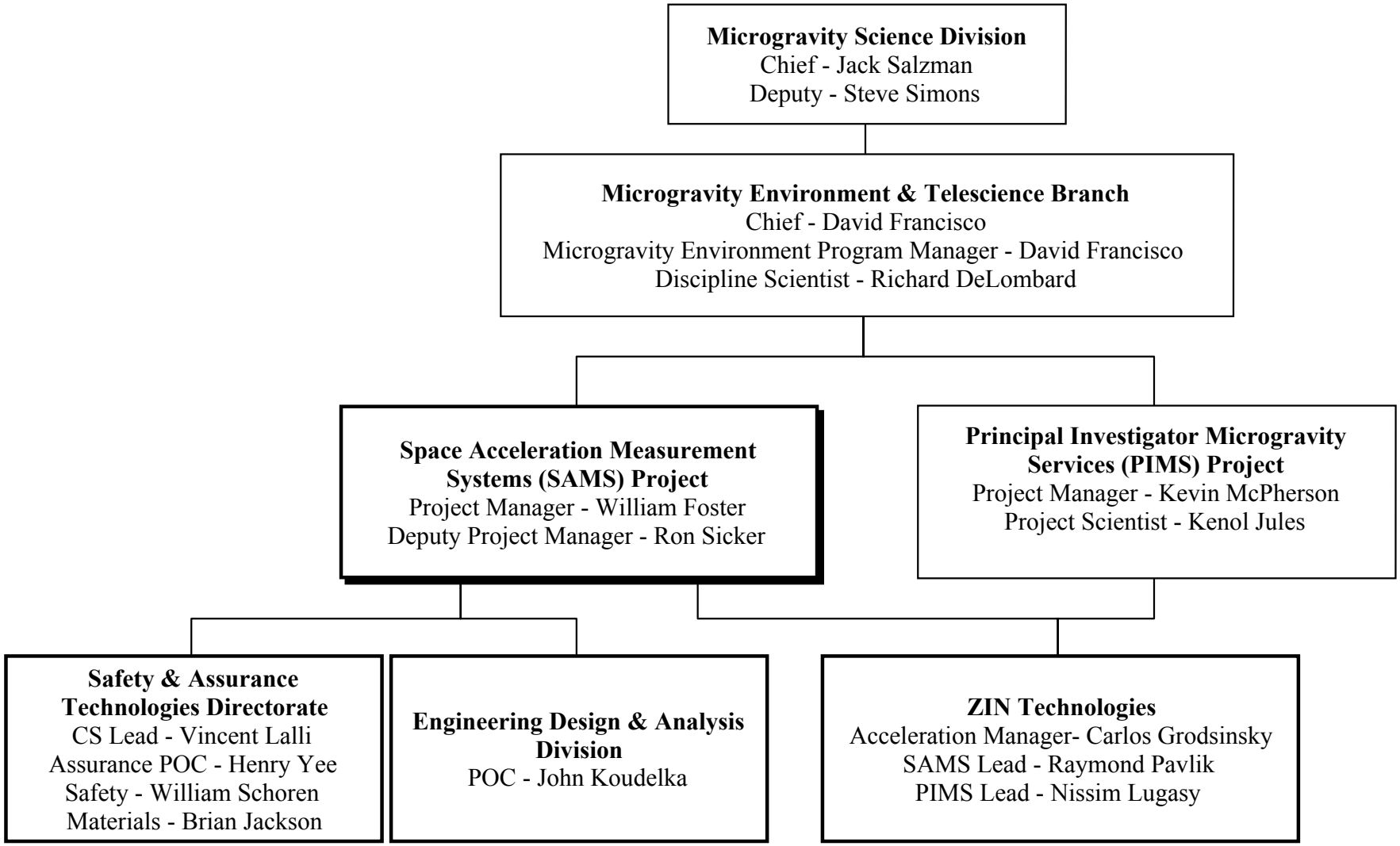
SAMS Project Purpose

The Space Acceleration Measurement Systems (SAMS) Project develops, deploys, and operates acceleration measurement systems to measure, collect, process, record, and deliver* selected acceleration data to researchers & other customers that require control, monitoring, and characterization of the microgravity environment on platforms and/or facilities such as drop towers, aircraft, sounding rockets, Space Transportation System (STS), and International Space Station (ISS).

SAMS is funded by the Physical Sciences Division (code UG) of the Office of Biological and Physical Research at NASA Headquarters.

*SAMS's sister project, Principal Investigators Microgravity Services (PIMS), provides extensive data analysis of the acceleration data based on customer requests and acts as the primary interface of the acceleration data to most researchers.

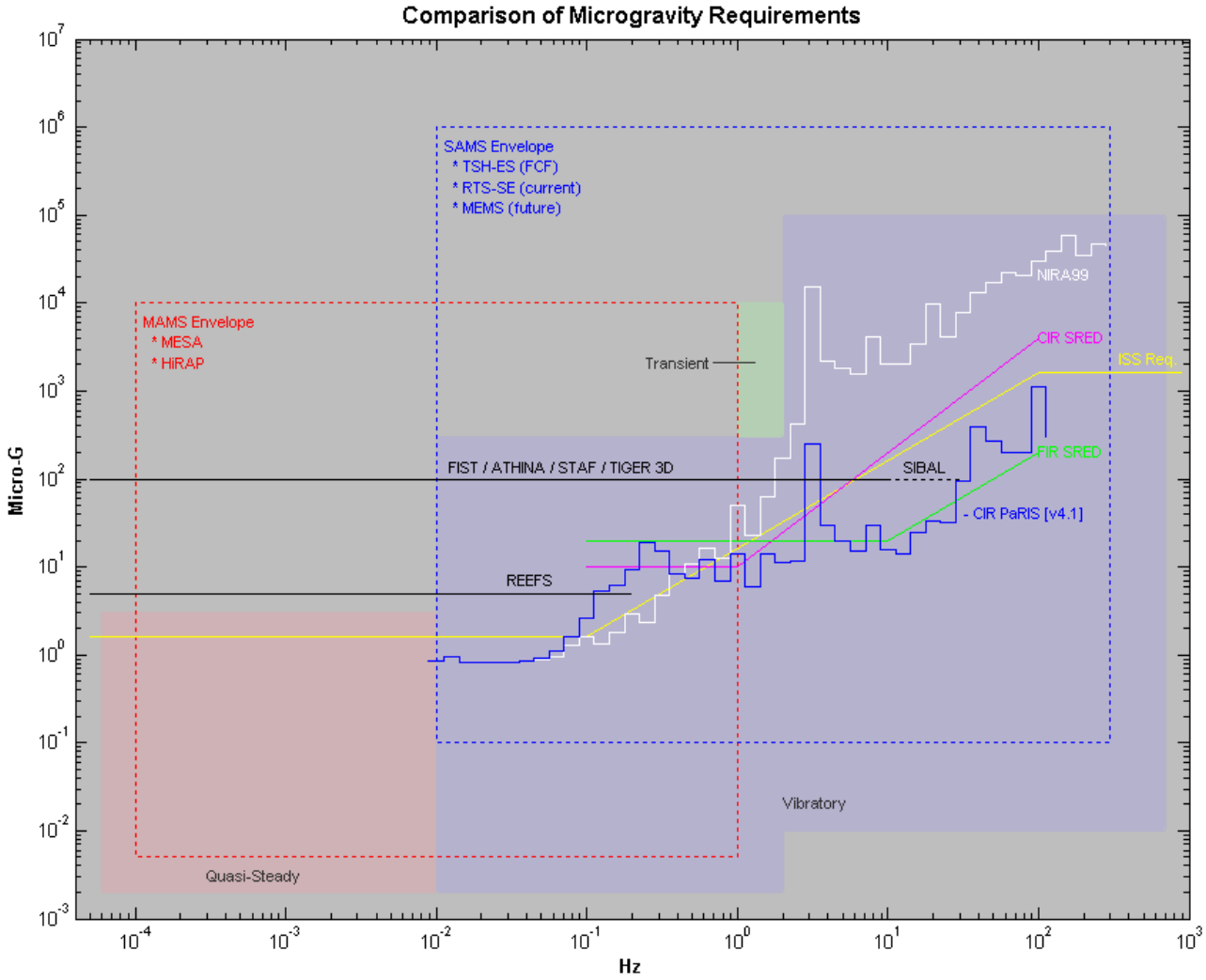
Organization



Microgravity Environment Measurement Requirements

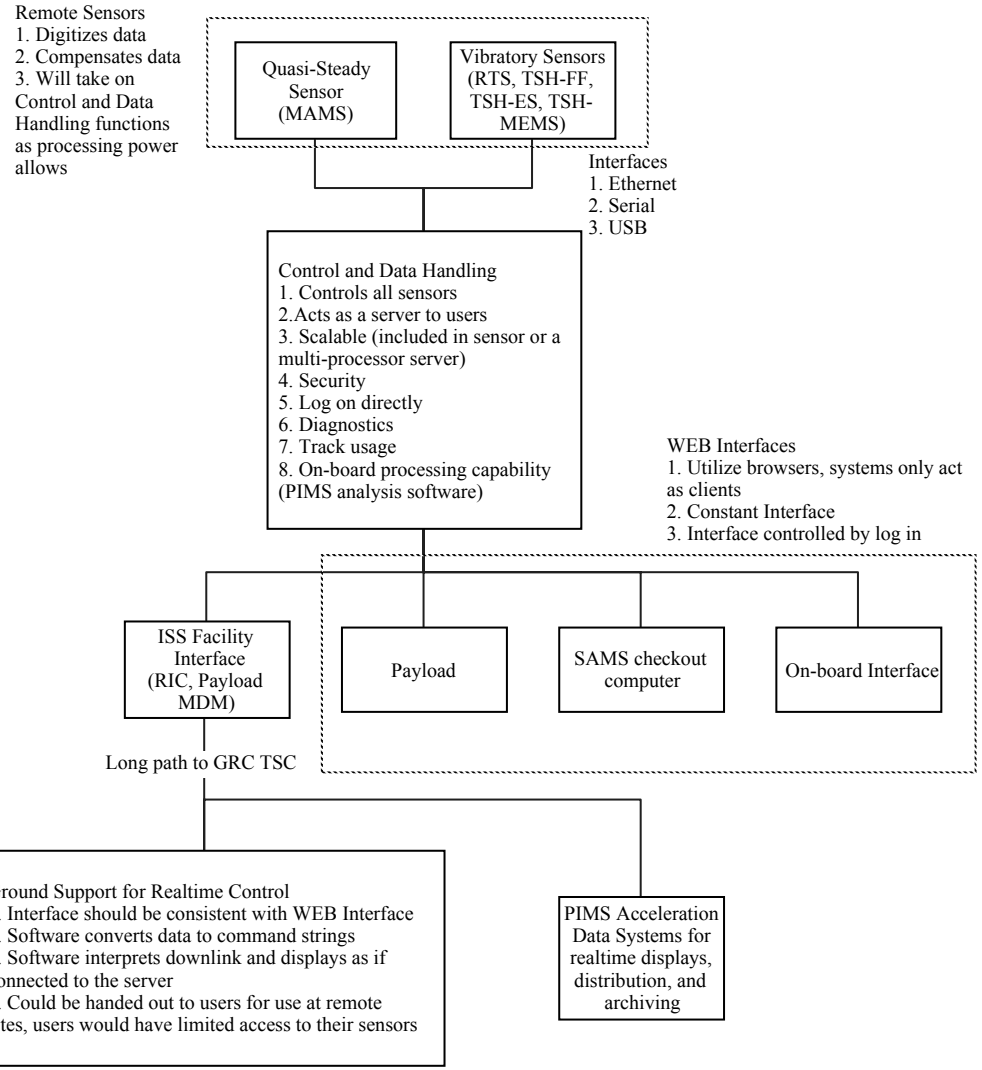
- PIMS-001 - Experiment Support Requirements Document (ESRD)
  - Acquire microgravity acceleration data.
    - Measure accelerations with an accuracy and resolution better than the acceleration environment envelope of the ISS program.
    - Acquire the acceleration data with correlated time information.
    - Measure acceleration within selectable frequency range.
    - Measure acceleration in, on and/or near the experiment sample/ chamber/ apparatus.
  - Allocate control of SAMS-II.
    - PI control of parameters.
    - On-orbit crew control of parameters.
  - Supply acceleration information to users.
    - Supply information in a selectable format.
    - Supply information within a selectable amount of time.

Measurement Requirements



SAMS System Philosophy

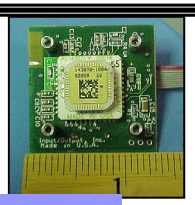
SSD #1005



Acceleration Measurement Systems

History
Present Systems
Future Systems

System Deployment



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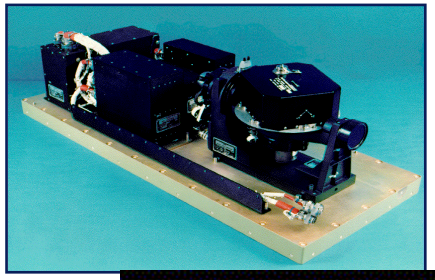
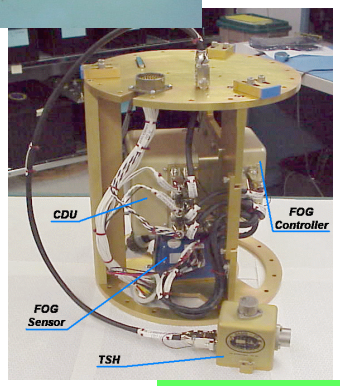
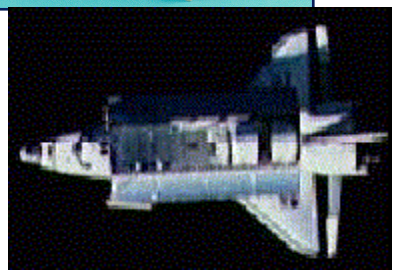






TSH-ES (0.01 to 400 Hz) Compact RTS

RTS (0.01 to 400 Hz)
Distributed ISS Vibratory System

MAMS-HiRAP (0.01 to 100 Hz)
ISS Vibratory System

MAMS-OSS (DC to 1 Hz)
ISS Quasi-steady System

RRS (0.1 arc/sec) 1 sounding rocket, 1 STS

TSH (0.01 to 200 Hz)
3 sounding rocket, 2 STS

OARE (DC to 1Hz) - 12 Shuttle Flights

7 SAMS/STS Units (0.01 to 100 Hz) 21 Shuttle/MIR Flights

SAMS Project Initiated

1986 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009

Sensors Being Deployed

- Vibratory Sensors (Q-Flex Accelerometers)
  - Triaxial Sensor Head for Free Flyers (TSH-FF)
    - Primary system for ground operations (drop towers, KC-135)
  - Remote Triaxial Sensor (RTS)
    - Modular expandable system to support ISS
  - Triaxial Sensor Head Ethernet/Standalone (TSH-ES)
    - Compact solution replacing RTS
  - Microgravity Acceleration Measurement System (MAMS) - HiRAP
    - Single system mounted in MAMS
- Quasi-Steady Sensors (Miniature Electro-Static Accelerometer)
  - Microgravity Acceleration Measurement System (MAMS) -OSS
    - OARE Sensor Subsystem (OSS)
- Roll Rate Sensor (RRS)
  - Measure rotational acceleration on sounding rockets

Triaxial Sensor Head (TSH)

- Measures vibratory acceleration data (0.01 to 200 Hz)
- Size: 2.9”x2.9”x2.8” & 1.1 lb
- Power: +/- 15VDC, 1.65W
- Communication: RS-422 serial
- Pendulous mass force balance accelerometers
- 3 orthogonal QA-3000/3100 units
- Temp. measurement (in QA-3000/3100)
- Digitizes acceleration & temp data
- Dynamic Range: 40 dB (0.1 µg to 1 g)
- Selectable Cutoff Frequency: 200, 100, 50, 25, 10, 2.5
- Data output to control unit
- Use with experimenter’s computer
  - Connect TSH, add power, and install software
  - Easy to synchronize data with other payload sensors
- Ground applications (non-ISS, STS)

TSH Missions

STS: HOST, STS-107
Sounding Rockets: SAL-6, DARTFire
KC-135: ugSEG, SoRGE, FEANICS

TSH/RRS Control and Data Handling

- Control & Data Acquisition Unit (CDU)
- Size: 5.3”x5.3”x5.0”
- PC/104 industrial grade embedded system with real-time control software for data and command
  - CPU board i486 processor
  - 6 GB rotational hard drive for data storage
  - Serial I/O board
  - Analog/Digital I/O board
  - Ethernet board interface to SH EDSMU
  - LCD display for status and checkout
- Conditions & distributes power to attached sensors

Remote Triaxial Sensor (RTS)

- Measures vibratory acceleration data (0.01 to 400 Hz)
- Components
  - **Electronics Enclosure (EE)**
    - Size: 9.1 in x 9.3 in. x 4.7 in. & 11 lb
    - Power: 28 VDC, 8 W
    - Communication: ethernet
    - PC/104 card stack (CPU, Ethernet, A/D, Control, Interface(2))
    - Supplies power to SE
    - Digitizes temp. data & compensates acceleration data
    - Controlled by & data output to control unit
  - **Sensor Enclosure (SE)**
    - Size: 5.6 in X 4.0 in. X 3.5 in. & 2.5 lb
    - Power: 2.25 W (supplied thru EE)
    - Pendulous mass force balance accelerometers (3 QA-3000/3100 units)
    - Alignment- orthogonality 0.1°; to base 0.5°
    - Temp. measurement (in QA-3000/3100)
    - Delta Sigma 24 bit A/D Converter per axis
    - Dynamic Range: 130 dB (0.1 µg to 1g)
    - Selectable Cutoff Frequency: 400, 200, 100, 50, 25 Hz
  - Custom Interface Cable (EE to SE's)
- EE mounts in ISS racks, SE on payloads

ISS EE Missions
- 122-F05 in EXPRESS Rack (ER) #2
- 122-F04, F01, F07 in ER #3, 7, 8
- 122-F06 in Microgravity Science Glovebox

ISS SE Missions
- 121-F06 Physics of Colloids in Space (PCS)
- 121-F02 PIMS
- 121-F03, F04, F05 ARIS-ICE
- 121-F08 Microgravity Science Glovebox
- 121-F06 Physics of Colloids in Space+ (PCS+)

Triaxial Sensor Head - Ethernet/Standalone (TSH-ES)

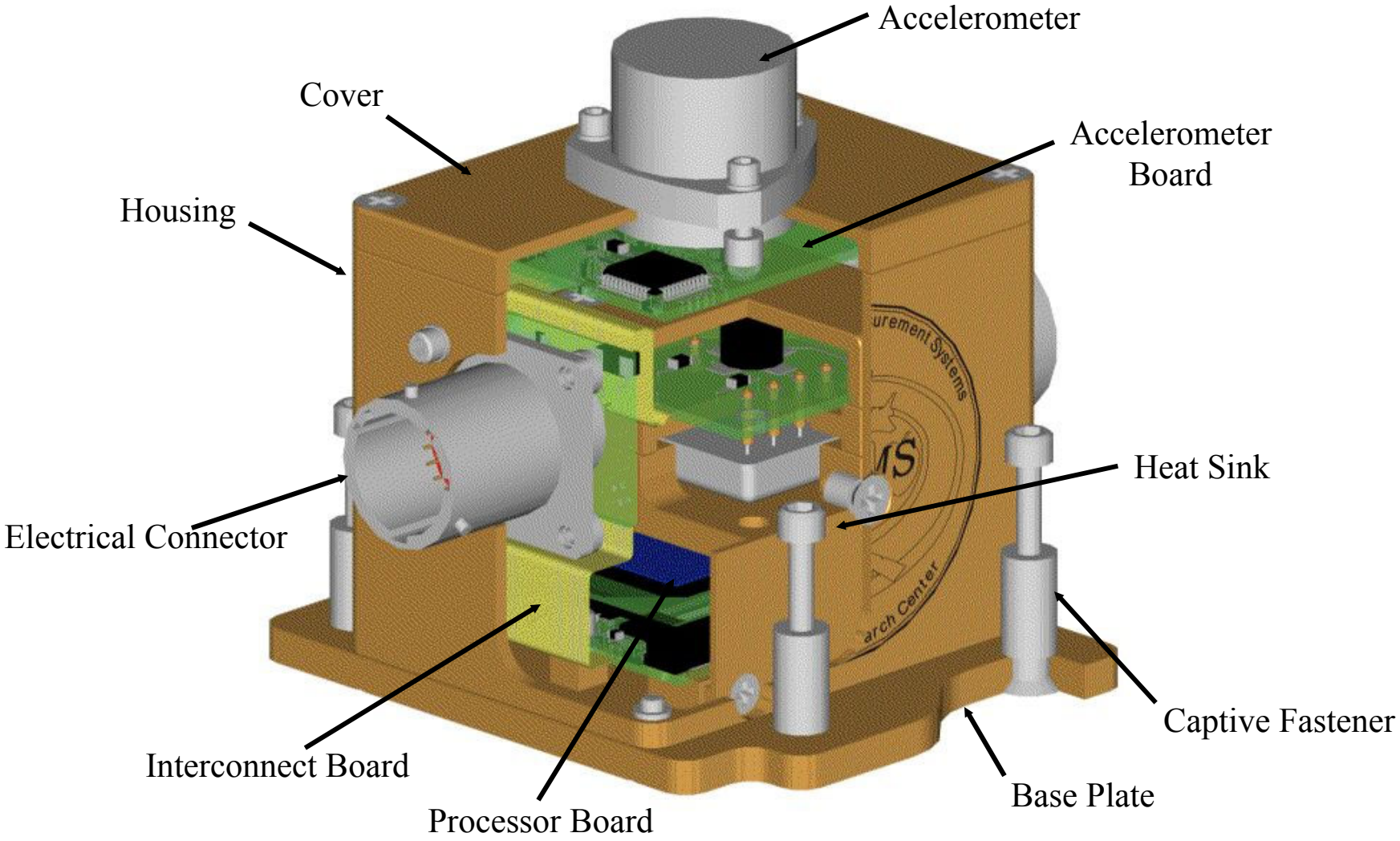
- Measures vibratory acceleration data (0.01 to 400 Hz)
- Size: 4.45”x3.65”x3.53” & 1.3 lb
- Power: +/- 15VDC, 4.5W; 28 V, 7.5W
- Communication: Ethernet, RS-232, USB
- Pendulous mass force balance accelerometers (3 QA-3100 units)
- Alignment- orthogonality 0.1°; to base 0.5°
- Temp. measurement (in QA-3100)
- Sigma-Delta 24 bit A/D Converter per axis for acceleration & temp data
- Dynamic Range: 135dB (0.1 µg to 1g)
- Selectable Cutoff Frequency: 400, 200, 100, 50, 25, 12, 10, 6, 3
- Maximized oversampling rate, High order Modulator, and cascaded decimating digital filters allow for maximizing the signal to noise ratio
- Data output to control unit (computer)
- Deployable on all platforms

ISS TSH-ES Missions

Have Agreements
- FCF (CIR & FIR)
- MSG (replaces a RTS)

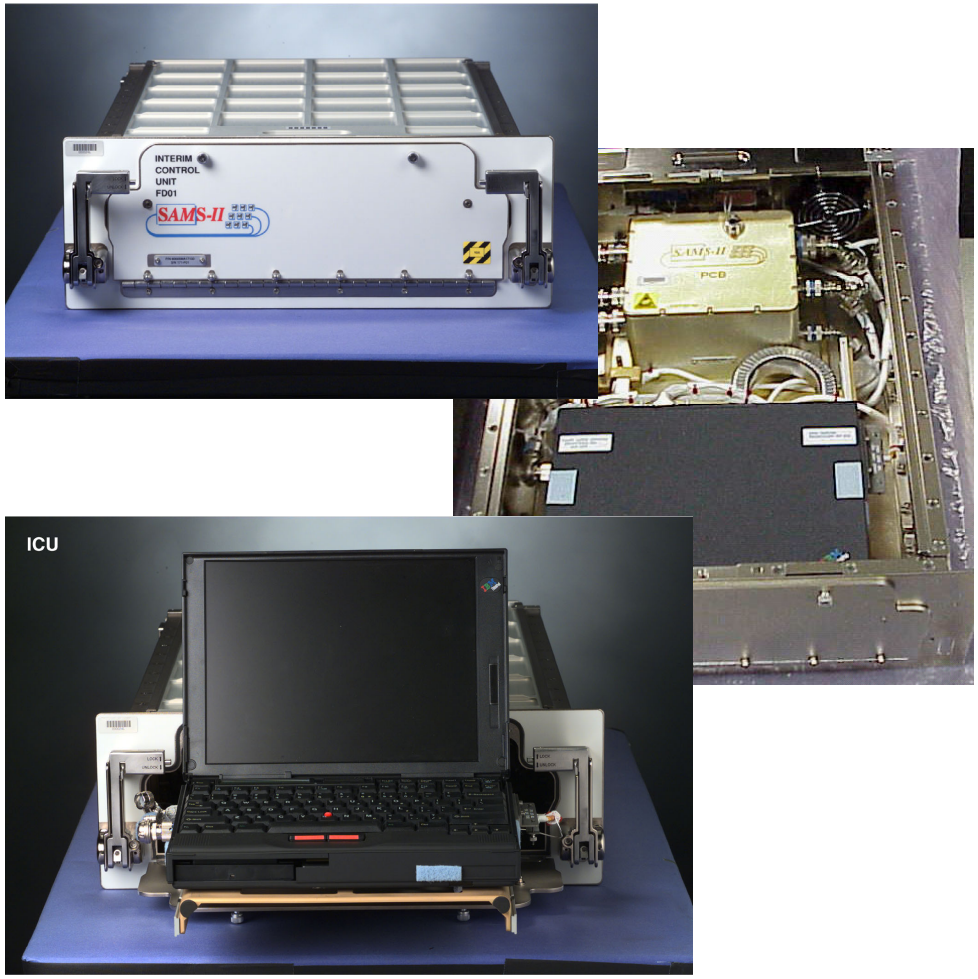
Working Agreements
- *LTMPF (outside deployment)*

TSH-ES Layout



RTS Control and Data Handling

- International Space Station (ISS)
  - Interim Control Unit (ICU)
  - IBM 760XD laptop, 3 GB & 30 GB hard drives. Modified for flight by ISS PCS.
- Loads program and software coefficients to RTS-EE
- Used to buffer and transmit data for telemetry
- Provides a crew interface for control and data display
- Capability to be added for TSH-ES

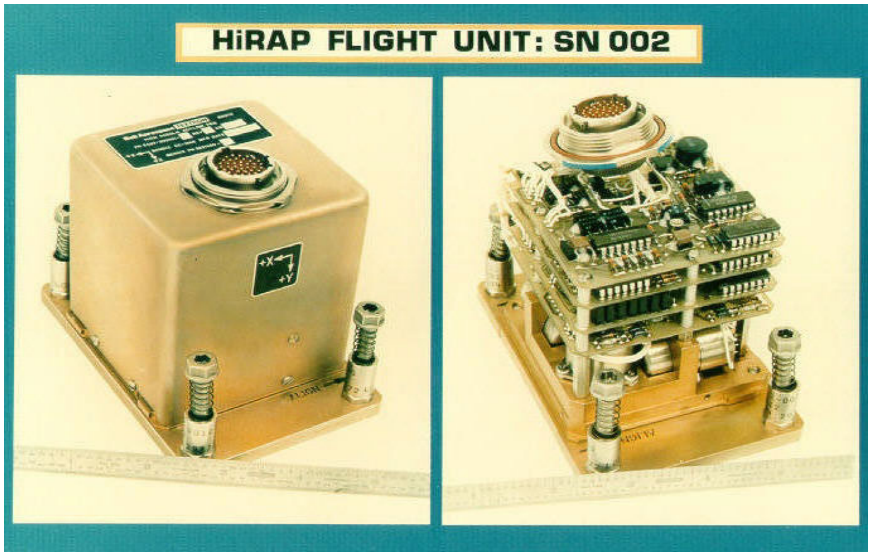


Microgravity Acceleration Measurement System (MAMS)

- Measures Quasi-steady & vibratory acceleration data (DC to 100 Hz)
- Size: 21.86”H x 18.37”W x 23.55”D
- Weight :117 lb
- Power: 28 VDC, 79 watts
- Communication: Ethernet EXPRESS Rack Interface Controller
- Location: EXPRESS Rack #1 Increment 2-5
- RIC Software Controller applies power after crew sets panel power switch to “ON”
- Thermal Control: Avionics Air Assembly cooling with internal circulating fan
- Two sensors - HiRAP & OSS

MAMS - High Resolution Accelerometer Package (HiRAP)

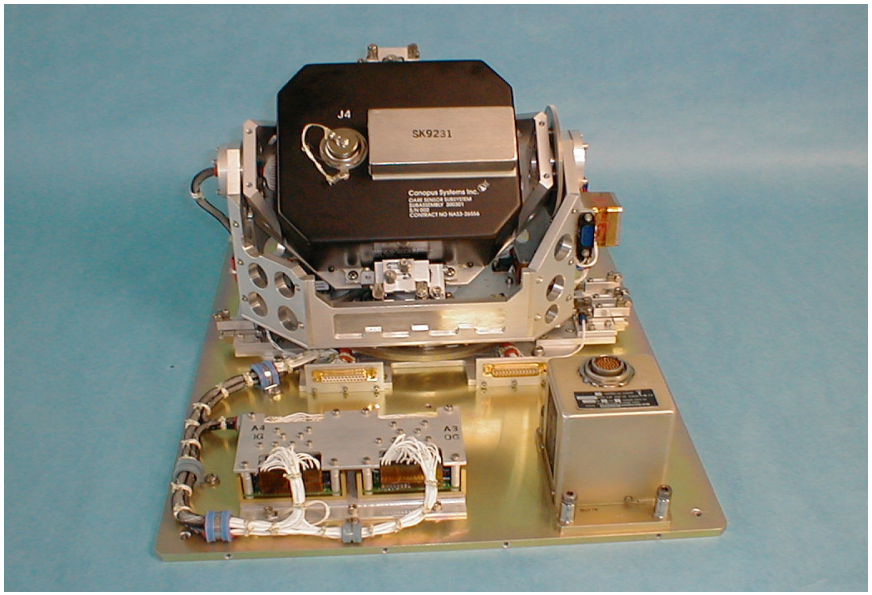
- Measures vibratory acceleration data (0.01 to 100 Hz)
- Communication: Digitized Data is sent to RIC for downlinking
- 3 orthogonal HiRAP sensing input axes
- Accuracy & resolution of 1/10th of the magnitude or one microgravity, whichever is greater, of the Space Station system acceleration limits from 0.01 to 100 Hz



- Backup for RTS on ISS
- Measures single location

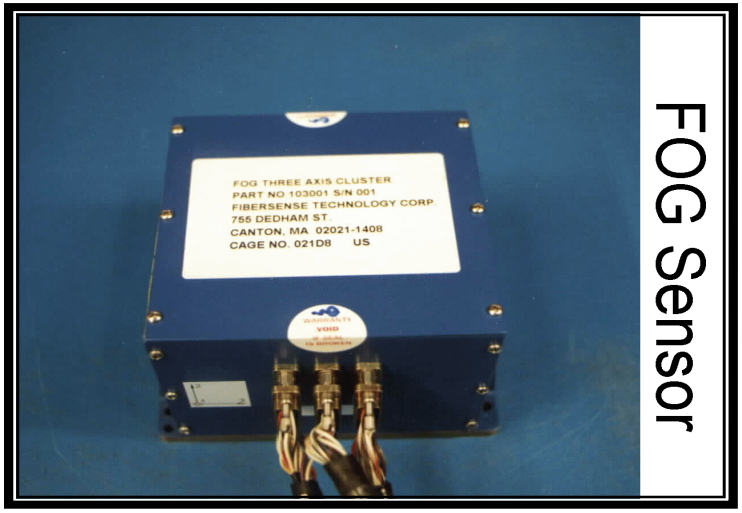
MAMS - OARE Sensor Subsystem (OSS)

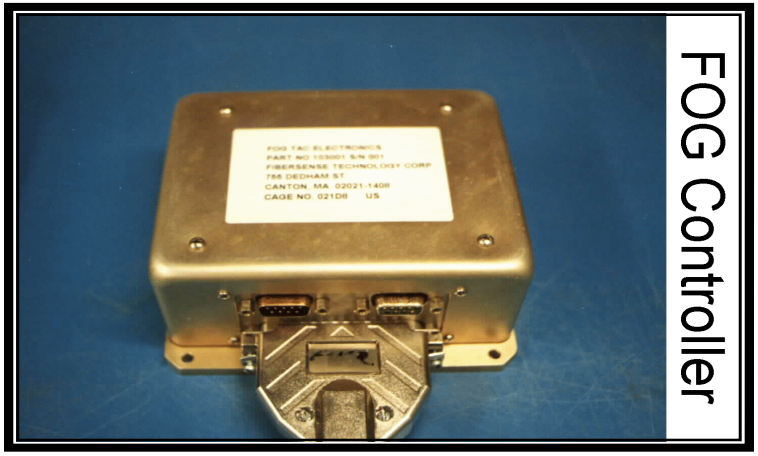
- Measures quasi-steady accelerations (DC to 1 Hz where "DC" is at least as low as 10^{-5} Hz)
- Communication: Digitized Data is sent thru ethernet to EXPRESS RIC for downlinking
- Electro-static suspended proof mass accelerometer
- 1 MESA sensor with 3 axes measurement
- On-Orbit calibration for temperature/drift compensation
- Accuracy and resolution of 100 nano-g or better from the orbital rate to 1.0 Hz
- Dynamic Range:
  - X axis: 3.1 nano-g to 10,000 micro-g
  - Y & Z axes: 4.6 nano-g to 25,000 micro-g



Roll Rate Sensor (RRS)

- Fiber Optics Gyroscope (FOG) - No moving parts
- Size: 3.8”x4.4”x3.0” (sensors), 4.8”x5.0”x2.2” (controller)
- Weight: < 4 lbs
- Power: ~10 W
- Measures vehicle roll rate by light wave phase shift in opposing fiber coils
- Resolution = 0.1 arc-secs





System Comparison Table

	TSH-FF	RTS	TSH-ES	MAMS	RRS
Description	3 QA-3100 Allied Signal Accelerometers	3 QA-3100 Allied Signal Accelerometers	3 QA-3100 Allied Signal Accelerometers	MESA and HiRAP Sensors, Calibration Table	Fiber Optic Gyroscope (Fibersense)
Measured Quantity	Vibratory Linear Acceleration	Vibratory Linear Acceleration	Vibratory Linear Acceleration	Quasi-steady Linear Accel.	Angular Acceleration
Dimensions (inches)	3.85x3.48x3.51	5.9x4.5x3.4 (SE) 9.1x9.3x4.7 (EE)	4.45x3.65x3.53	21.9x18.4x23.6	3.8x4.4x3.0 (Gyro) 4.8x5.0x2.2 (Intf)
Weight (lbs)	1.1	2.5 (SE) 11 (EE)	1.3	117	3.75
Power (W)	1.6	2.25 (SE) 8 (EE)	+/- 15VDC, 4.5W; 28 V, 7.5W	79	~10
Data Interface	RS-422	Ethernet	Ethernet, RS-232, USB	Ethernet	RS-232
Bandwidth	0.01-200 Hz	0.01-400 Hz	0.01-400 Hz	DC (10^{-5})-1 Hz (MESA) 10^{-4}-100 Hz (HiRAP)	10 Hz Sampling
Maximum Scale	1.25 g	1.1 g at G=1 0.11 g at G=10	1.1 g at G=1 0.13 g at G=8.5	10-25 mg (MESA) 16 mg (HIRAP)	190¡/sec
Resolution	0.1 µg	0.1 µg 0.1/0.01 µg A/D	0.1 µg	3-4.6 ng (MESA) 1 µg (HiRAP)	0.1 arc-sec
Current platforms/ facilities supported	sounding rocket, KC-135, ground facilities	ISS	ISS (will deploy on all platforms in the future)	ISS	STS, sounding rocket

Comparison of Vibratory Sensors

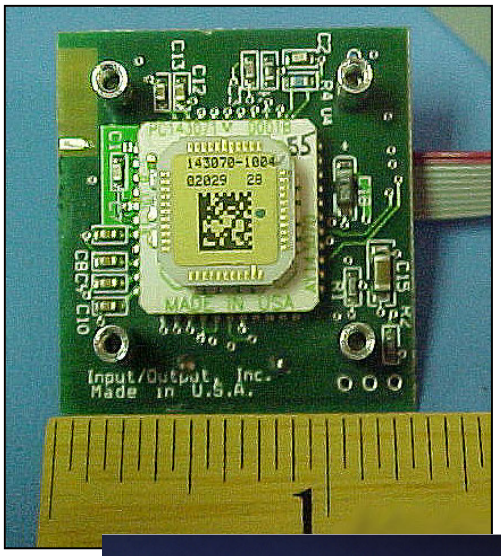
			TSH-ES	RTS	TSH-FF
Passband Bandwidth at -3dB Point	Minimum	Hz	3.2	25.7	2.62
	Maximum	Hz	408.5	411.9	209.6
A/D Converter	Type		ΣΔ	ΣΔ	ΣΔ
	Resolution	Bits	24	24	24
	Component		AD1555	CS5320	HI7190
Sensor	Component		QA3100	QA3100	QA3000
A/D Thermal Offset Drift		mV/¡C	6	60	1
Front End Thermal Offset Drift		mV/¡C	0.015	0.25	0.2
Modulator	Order		4	4	2
	Frequency	KHz	256	256	128
Oversampling Ratio	Minimum		256 @ 1000Hz	256 @ 1000Hz	72 @ 800Hz
	Maximum		32768 @ 7.8Hz	4096 @ 62.5Hz	5760 @ 10Hz
Digital Filter			FIR	FIR	Sinc3
Input Analog Filter	Order		2nd	1st	2nd
	Type		Active	Passive	Active
Processor			PowerPC MPC850	386	87C51FB
Input Power		V	±15 or 28	28	± 15
Communication			Ethernet, RS232, USB	Ethernet	RS422
Programmable Gain Amplifier			Yes	Yes	Yes
Stopband Attenuation		dB	135	130	40
Power		W	4.5 (15V) 7.5 (28V)	2.25 SE, 8 EE	1.67
Dimensions	Height	In	3.53	3.44 SE, 4.7 EE	3.51
	Width	In	3.65	4.53 SE, 9.3 EE	3.48
	Length	In	4.45	5.87 SE, 9.1 EE	3.85
Weight		lb	1.3	2.46 SE, 11 EE	1.1
Operating Temperature		¡C	0 to +50	0 to+70	-40 to +85 *
Storage Temperature		¡C	0 to +70	0 to+70	-55 to +125 *
* from component specs					

Future Development

- Currently Funded
  - Sensor Size Reduction
    - Packaging Improvements Utilized
    - Sensor Miniaturization Technology Considered
    - Combination of existing systems and upgrades
    - MEMS Technology
  - Software Modifications to support communication of other Acceleration Systems with ISS Control Unit (ICU)
  - Control Unit to replace ICU (ICU life is 3 years)
  - Identification of Disturbance Signatures on User Displays
  - Study to look at replacement of MAMS
- Possible Funded Work
  - Sensor mounting plates (enable sensors to be moved around in lab easily
  - MAMS upgrade (5 year life)

Triaxial Sensor Head with MEMS Accelerometer (TSH-MEMS)

- Currently under development
- Funded by Instrument Technology Development grant from NASA Headquarters
- Reduced size, weight and power compared to current TSH designs
- Allow for mounting several sensors at the area of interest (>10 Hz)
- Goal is to approach performance achieved by current TSH design.
- Performance limited by:
  - Smaller size of MEMS sensor limits low frequency response
  - Silicon sensor is more sensitive to temperature changes than currently used quartz sensors
  - Component selection for size and power reduction
- Control through RS-422 interface (1st generation)
- Working towards Ethernet

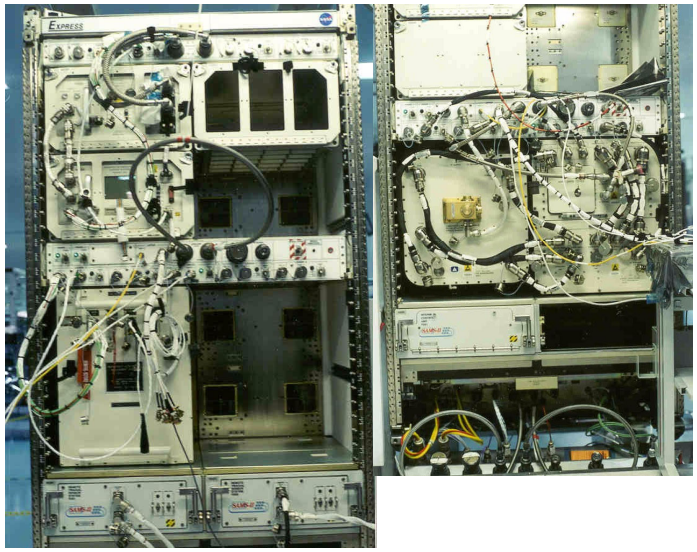


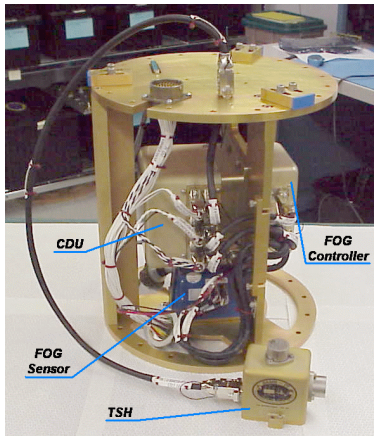
Applied MEMS (Input/Output Company) SF1500A MEMS Accelerometer is the selected sensor for the TSH-MEMS

Examples of Deployment

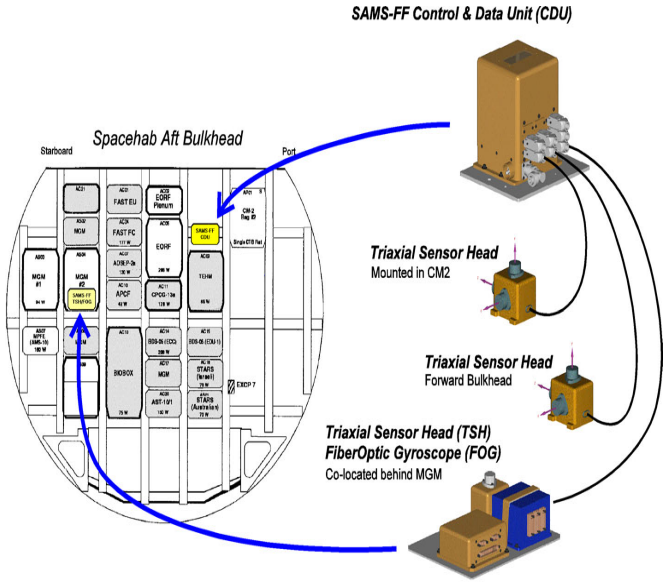
Space Flight Carriers

International Space Station
Sensors: RTS, TSH, MAMS
Control System: Interim Control Unit





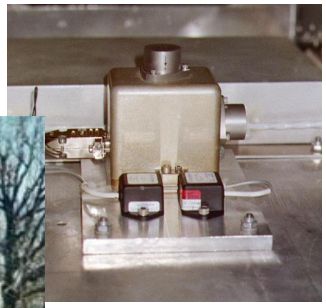
Space Shuttle
Sensors: TSH, FOG, OARE
Control System: Control & Data Acquisition Unit



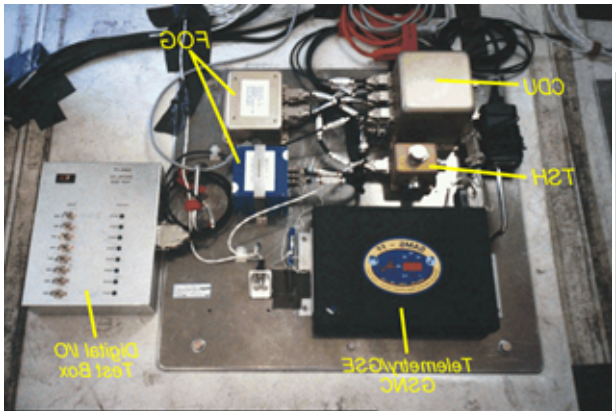
Sounding Rocket
Sensors: TSH, FOG
Control System: Control & Data Acquisition Unit

Aircraft and Ground Facilities

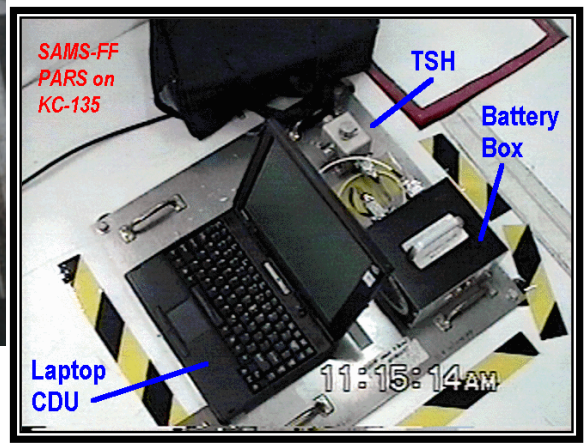
Drop Tower
Sensors: TSH
Control System: Control & Data Acquisition Unit



Plum Brook Station
Sensors: TSH
Control System: Space Power Facility Computer with SAMS software



KC-135
Sensors: TSH, FOG
Control System: Control & Data Acquisition Unit



Parabolic Aircraft Rating System
Sensors: TSH
Control System: PC Laptop with SAMS Software

Customers - How to request SAMS.

How to get a sensor or system

- Fill out PIMS questionnaire

  http://pims.grc.nasa.gov/html/RequestDataPlots.html
- Contact SAMS (see last page) to identify need.
- SAMS will provide a questionnaire based on platform

  Available soon on http://sams.grc.nasa.gov
- SAMS will include new work in project scope
  - Memorandum of Understanding (MOU) will be created
  - An Integration Control and Agreement Document (ICAD) will be created for STS or ISS
- SAMS will provide a system based on the MOU and/or ICAD

Conclusion

- The SAMS Project has several systems that can be configured to support a variety of microgravity platforms
- SAMS and PIMS will work with you to find the best system for your purposes

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