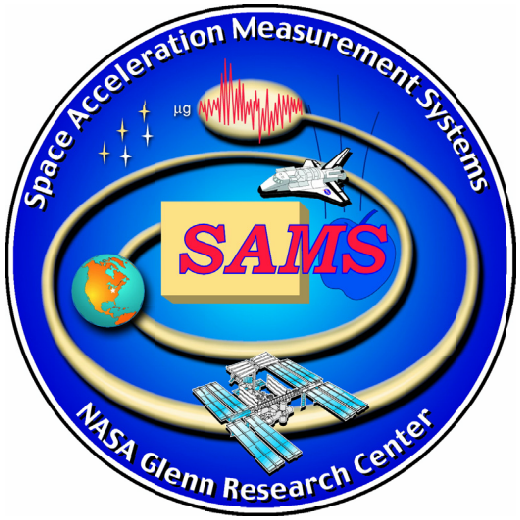


Acceleration Measurement Systems provided by the Space Acceleration Measurement Systems (SAMS) Project

William M. Foster II

Agenda

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

Acronyms

- AIDD — Agreement and Interface Definition Document
- CIR — Combustion Integrated Rack
- EE — Electronics Enclosure
- EXPRESS — Expedite the Processing of Experiments to Space Station
- FCF — Fluids and Combustion Facility
- FIR — Fluids Integrated Rack
- HiRAP — High Resolution Accelerometer Package
- MAMS — Microgravity Acceleration Measurement System
- MEMS — Micro-electromechanical systems
- OARE — Orbital Acceleration Research Experiment
- OSS — OARE Sensor Subsystem
- PIMS — Principal Investigator Microgravity Services
- RRS — Roll Rate Sensor
- RTS — Remote Triaxial Sensor
- SAMS — Space Acceleration Measurement Systems
- SE — Sensor Enclosure
- TSH — Triaxial Sensor Head (ES - Ethernet/Standalone, FF - Free Flyer, M - MEMS, Q - Quasi-steady)

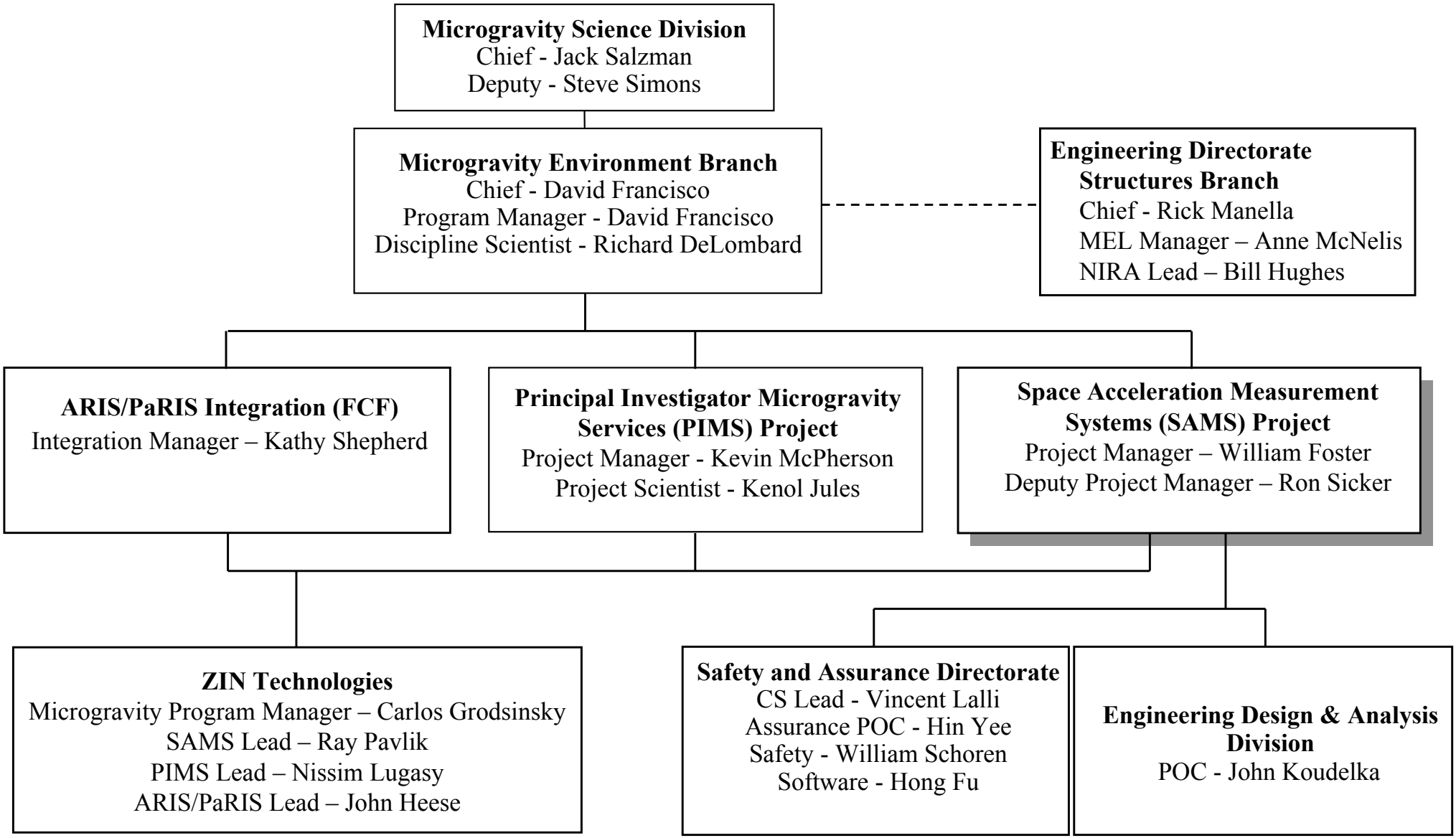
SAMS Project Purpose

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, and International Space Station.

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.

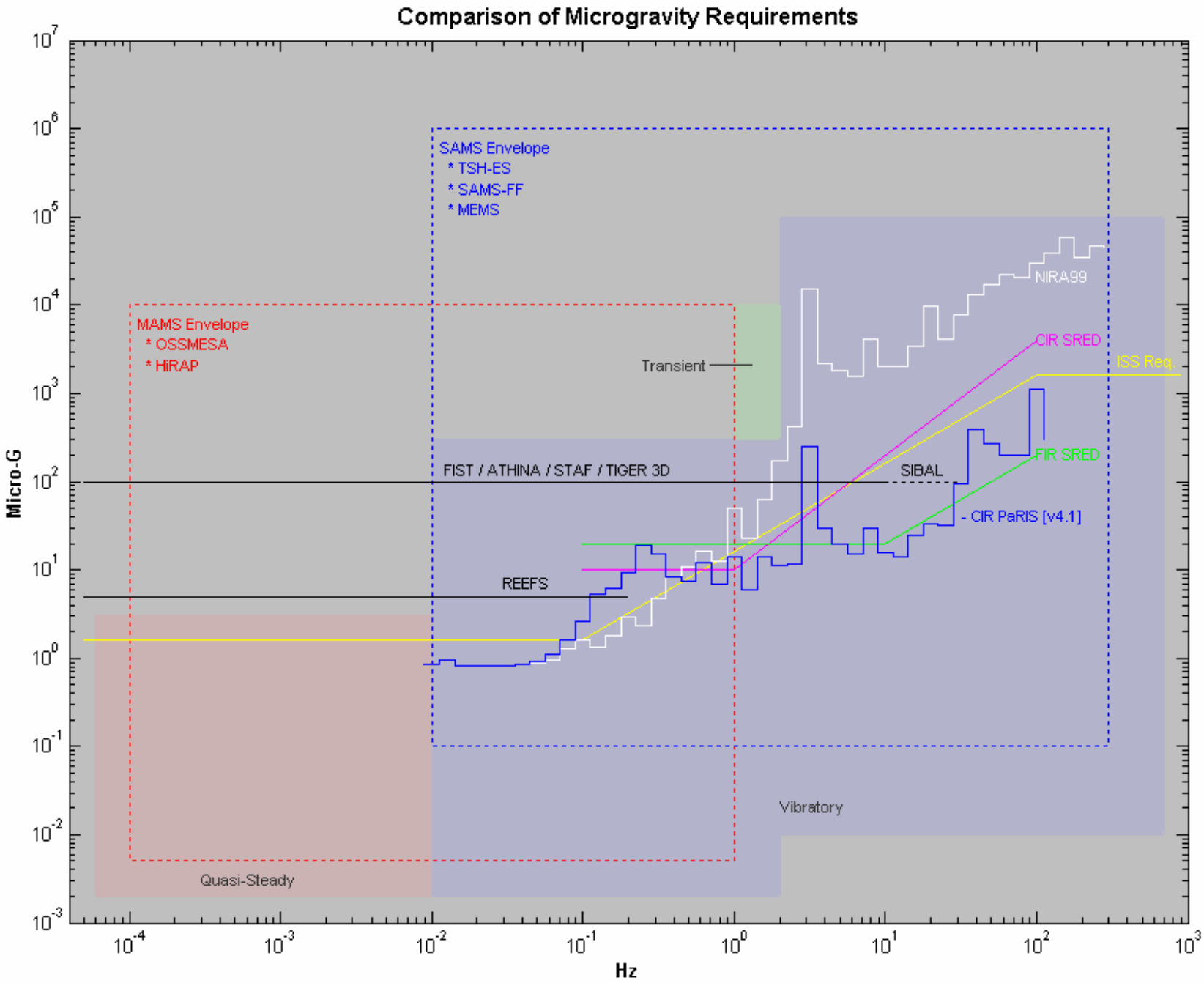
Microgravity Environment Program (MEP) Organization



Microgravity Environment Measurement Requirements

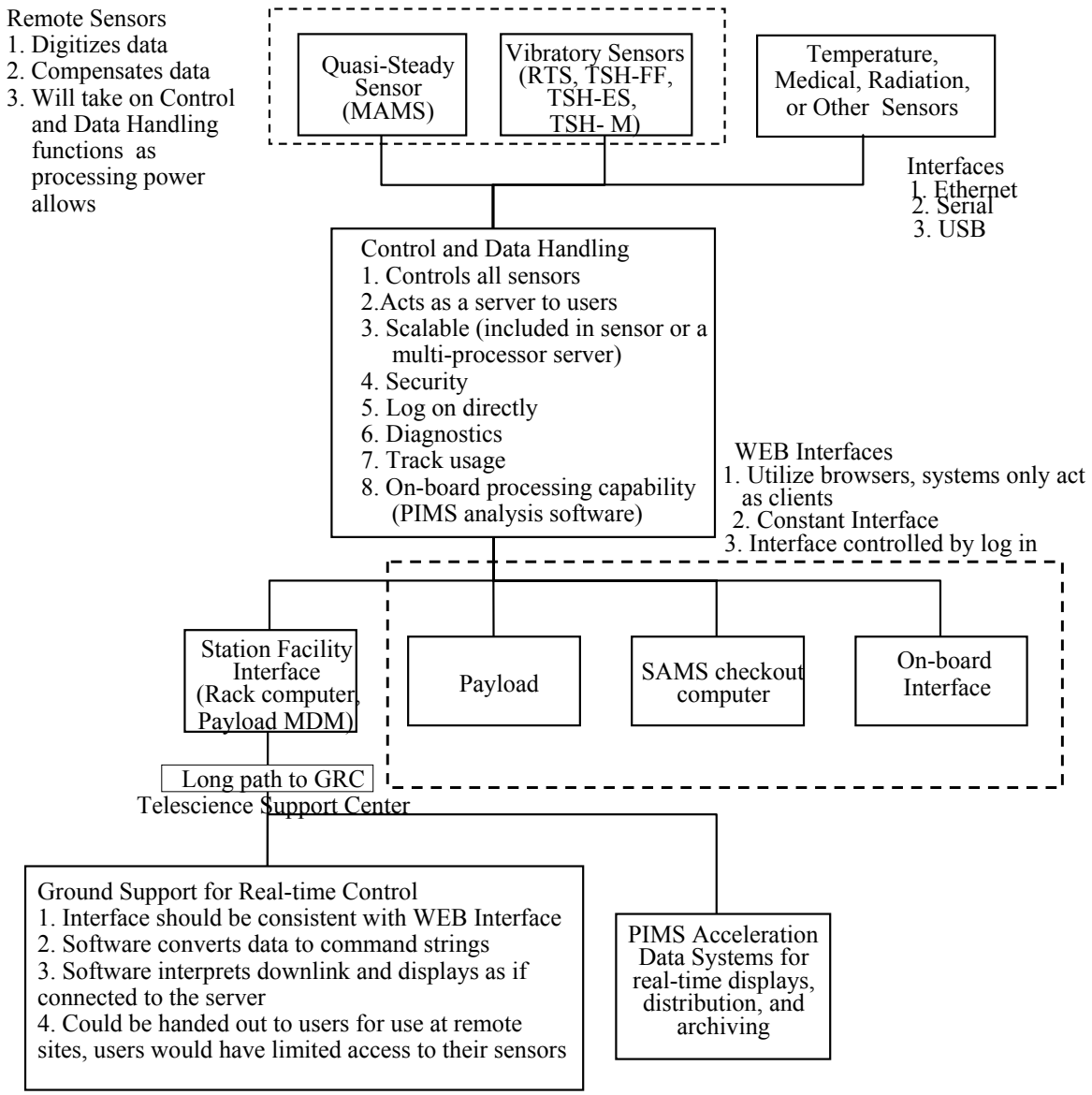
- PIMS-001 - Experiment Support Requirements Document

  - Acquire microgravity acceleration data.
    - Measure accelerations with an accuracy and resolution better than the acceleration environment envelope of the International Space Station 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.
    - Principal Investigator 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.


Comparison of Microgravity Requirements
SAMS Envelope
* TSH-ES
* SAMS-FF
* MEMS
MAMS Envelope
* OSSMESA
* HiRAP
Transient
NIRA99
CIR SRED
ISS Req.
FIR SRED
- CIR PaRIS [v4.1]
FIST / ATHINA / STAF / TIGER 3D
SIBAL
REEFS
Vibratory
Quasi-Steady
Micro-G
Hz

SAMS System Philosophy

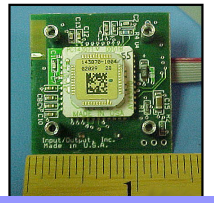
SSD #1005



Acceleration Measurement Systems

History
Present Systems
Future Systems

System/Sensor Deployment



QuickTime™ and a
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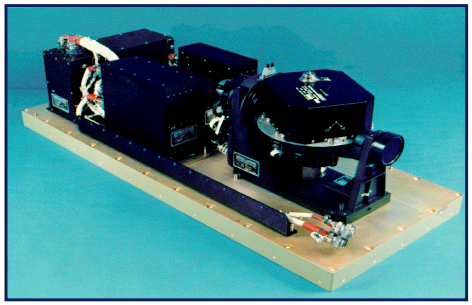
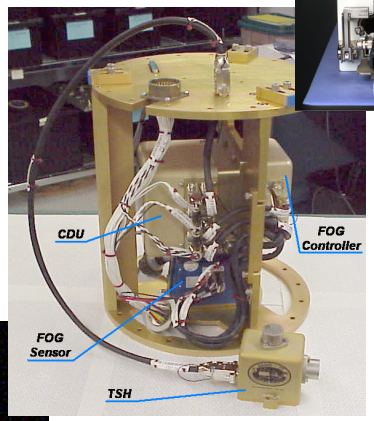
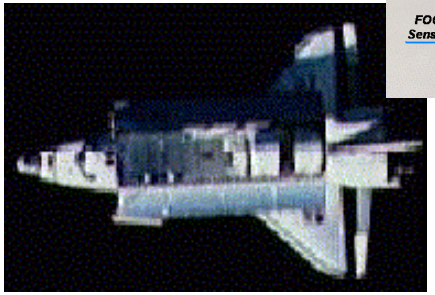
are needed to see this picture.







TSH-Q (10^{-5} to TBD Hz)
Quasi-steady Sensor - Versatile

TSH-M (1 to TBD Hz)
Vibratory MEMS - Versatile

TSH-ES (0.01 to 400 Hz)
Compact RTS-Ethernet/Standalone

RTS (0.01 to 400 Hz)
Ethernet Distributed Vibratory System

MAMS-HiRAP
(0.01 to 100 Hz) Station Vibratory

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

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

TSH-FF (0.01 to 200 Hz)
3 sounding rocket, 2 shuttle

OARE (DC to 1Hz) - 12 shuttle flights

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

SAMS Project Initiated

1986 1991 1994 1997 2000 2003 2006 2009 2012 2015 2018

Triaxial Sensor Head - Free Flyer (TSH-FF)

- 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
- Can use with experimenter’s computer
  - Connect TSH-FF, add power, and install software
  - Easy to synchronize data with other payload sensors
- Ground applications

TSH-FF Missions

Shuttle: 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
  - 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 (386 CPU, Ethernet, A/D, Control, Interface(2))
    - Handles power and communication for SE
    - Digitizes temp. data & compensates acceleration data
    - Gets commands & output data 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 International Space Station racks, SE on payloads

EE Missions

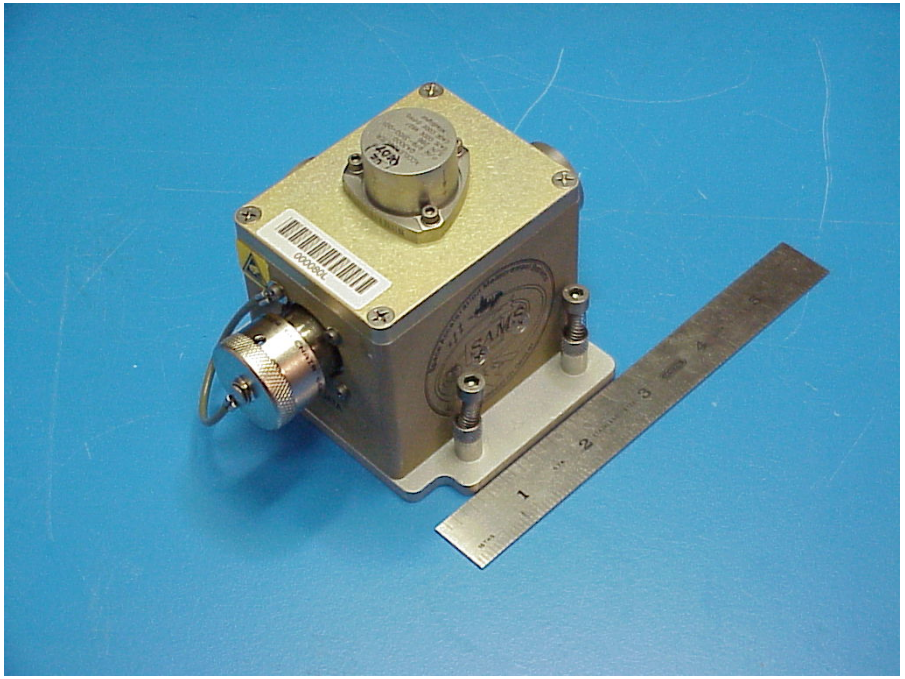
122-F05 in EXPRESS Rack (ER) #2
122-F02, F03 ARIS-ICE, Characterization
122-F04, F01, F07 in ER #3, 7, 8
122-F06 in Microgravity Science Glovebox

SE Missions

121-F06 Physics of Colloids in Space (PCS)
121-F02 PIMS for Characterization
121-F03, F04, F05 ARIS-ICE, Characterization
121-F08 Microgravity Science Glovebox
121-F06 Physics of Colloids in Space+ (PCS+) & PCS 3

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

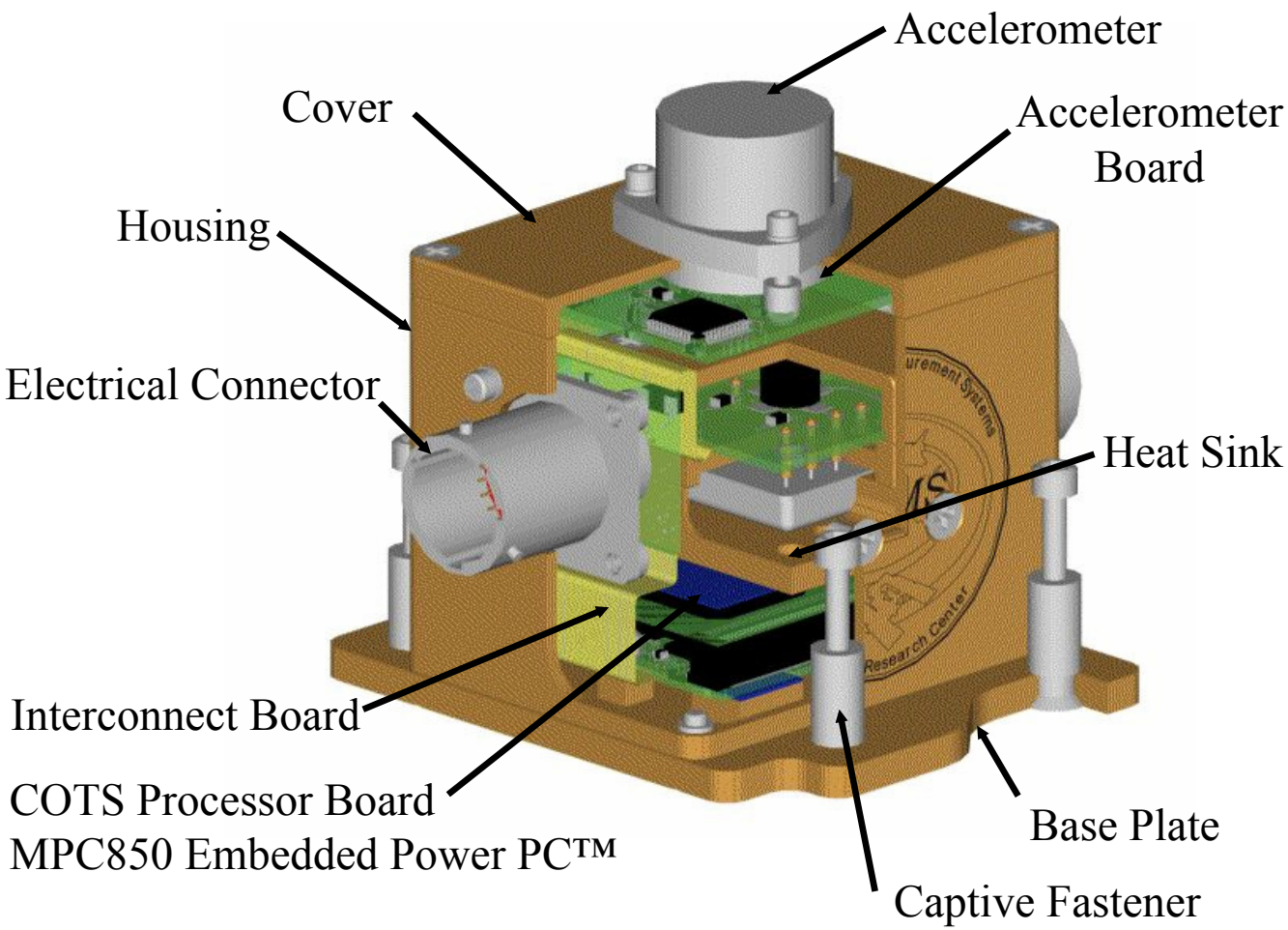
- Measures vibratory acceleration data (0.01 to 400 Hz)
- Size: 4.45”x3.65”x3.53” & 1.74 lb
- Power: +/- 15VDC, 4.5W; 28 V, 7.5W
- Communication: Ethernet, RS-232, USB
- Pendulous mass force balance accelerometers (3 QA-3100 units)
- Alignment- orthogonality 0.1°; to base 0.5°
- Temp. measurement (in 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 (or any ethernet computer)
- Deployable on all platforms

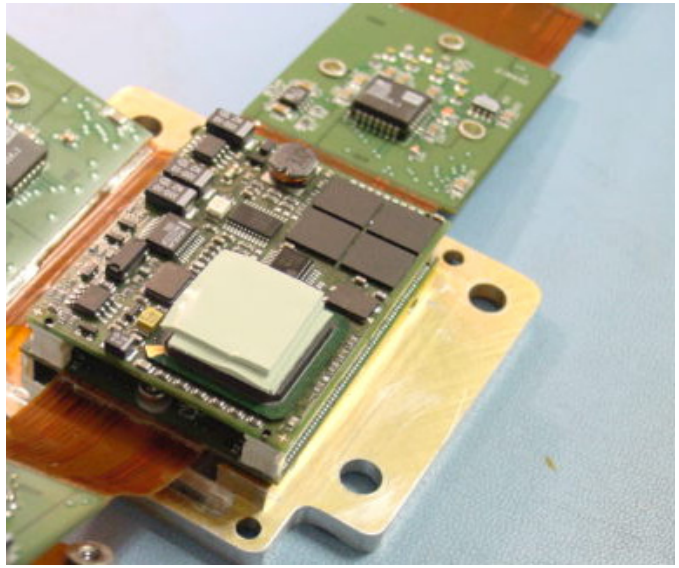


International Space Station Missions
Have Agreements
- FCF (CIR & FIR)
- MSG (replaces a RTS)

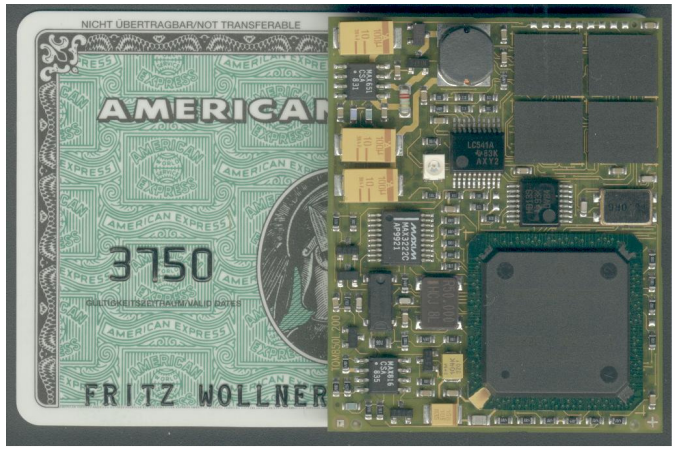
Working Agreements
- *BiDSL (MSG payload)*
- *LTMPF (outside deployment)*

TSH-ES Layout



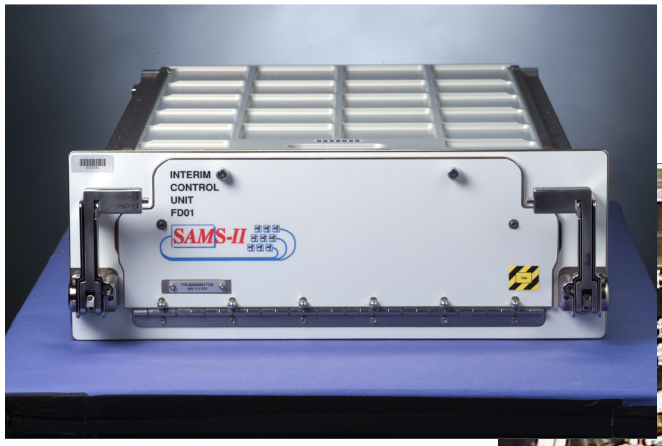


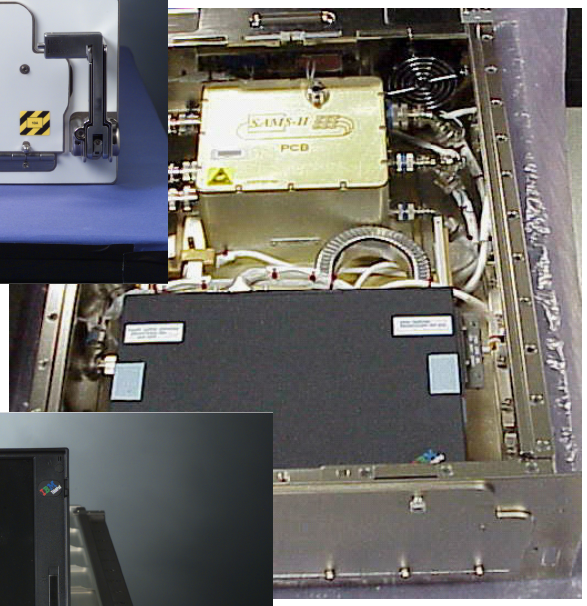
COTS Processor Board
MPC850 Embedded Power PC™



RTS Control and Data Handling

- International Space Station
  - Interim Control Unit
  - IBM 760XD laptop, 3 GB & 30 GB hard drives. Modified for flight by International Space Station 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 (10^{-5} 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 thru rack
- Location: EXPRESS Rack #1 Increment 2-8
- EXPRESS Rack Interface Controller Software Controller applies power after crew sets power switch to “ON”
- Thermal Control: Avionics Air Assembly cooling with internal circulating fan
- Two sensors - HiRAP & OSS

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

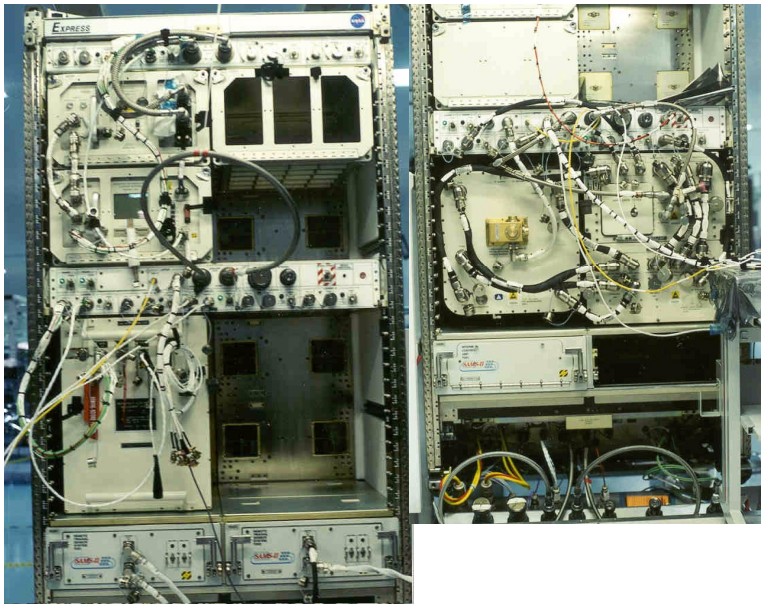
Future Development

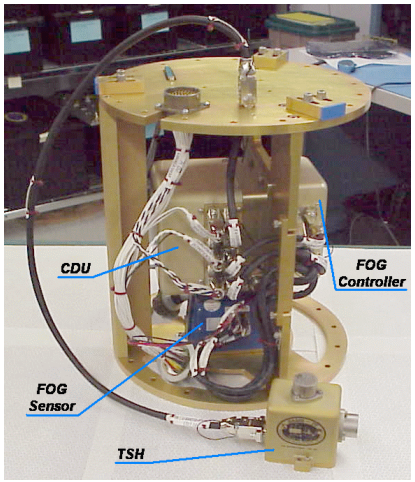
- Currently Funded
  - Sensor size reduction
    - Packaging improvements utilized
    - Sensor miniaturization technology considered
    - Combination of existing systems and upgrades
    - MEMS technology
  - Software modifications to increase capabilities based on customer requirements
  - Sensor mounting plates (enable sensors to be moved around in lab easily
  - Identification of disturbance signatures on user displays
  - Study to look at replacement of MAMS with MEMS sensors
- Possible Funded Work
  - Control Unit to replace Interim Control Unit, Interim Control Unit life is 3 years
  - MAMS upgrade (5 year life)

Examples of Deployment

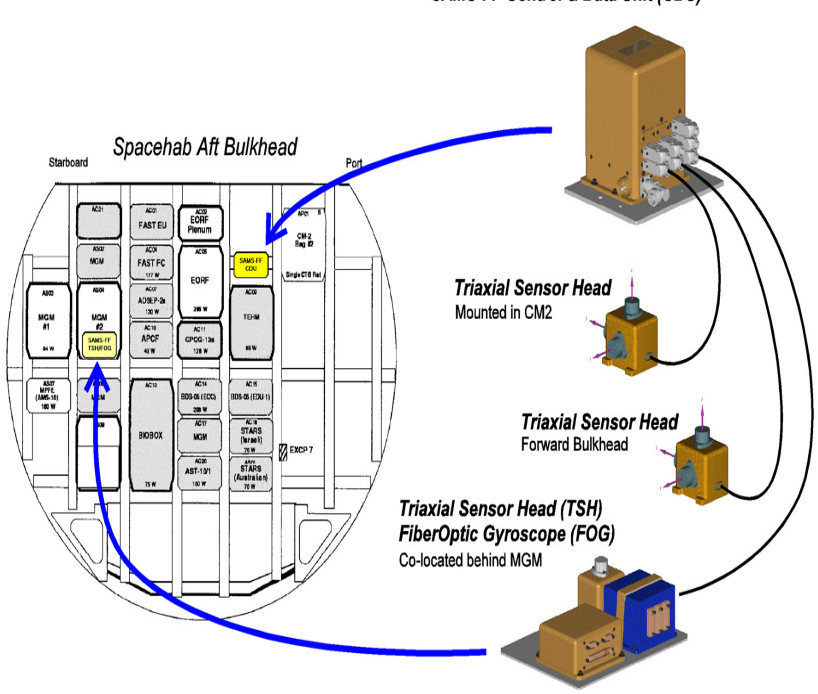
Space Flight Carriers

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





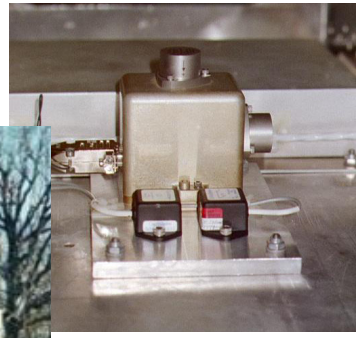
Space Shuttle
Sensors: TSH-FF, RRS, OARE
Control System: Control & Data Acquisition Unit



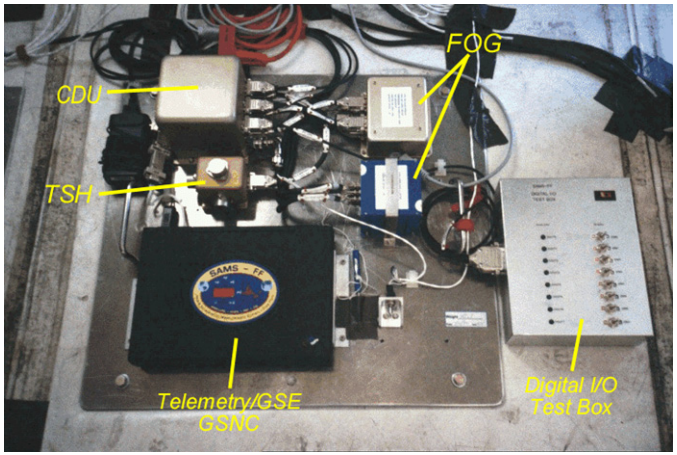
Sounding Rocket
Sensors: TSH-FF, RRS
Control System: Control & Data Acquisition Unit

Aircraft and Ground Facilities

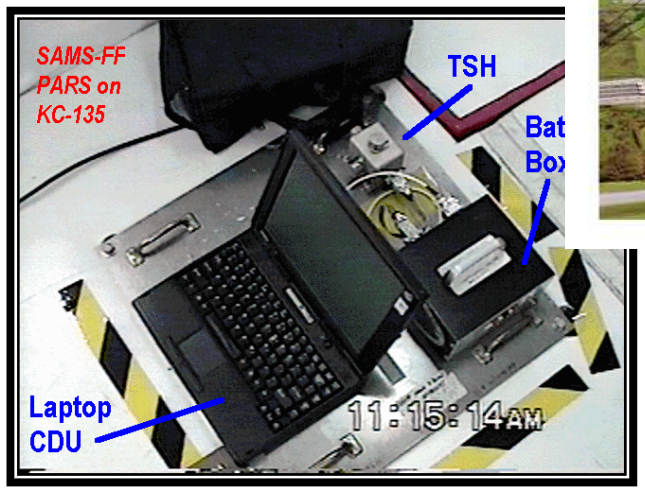
Drop Tower
Sensors: TSH
Control System: Control & Data Acquisition Unit



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



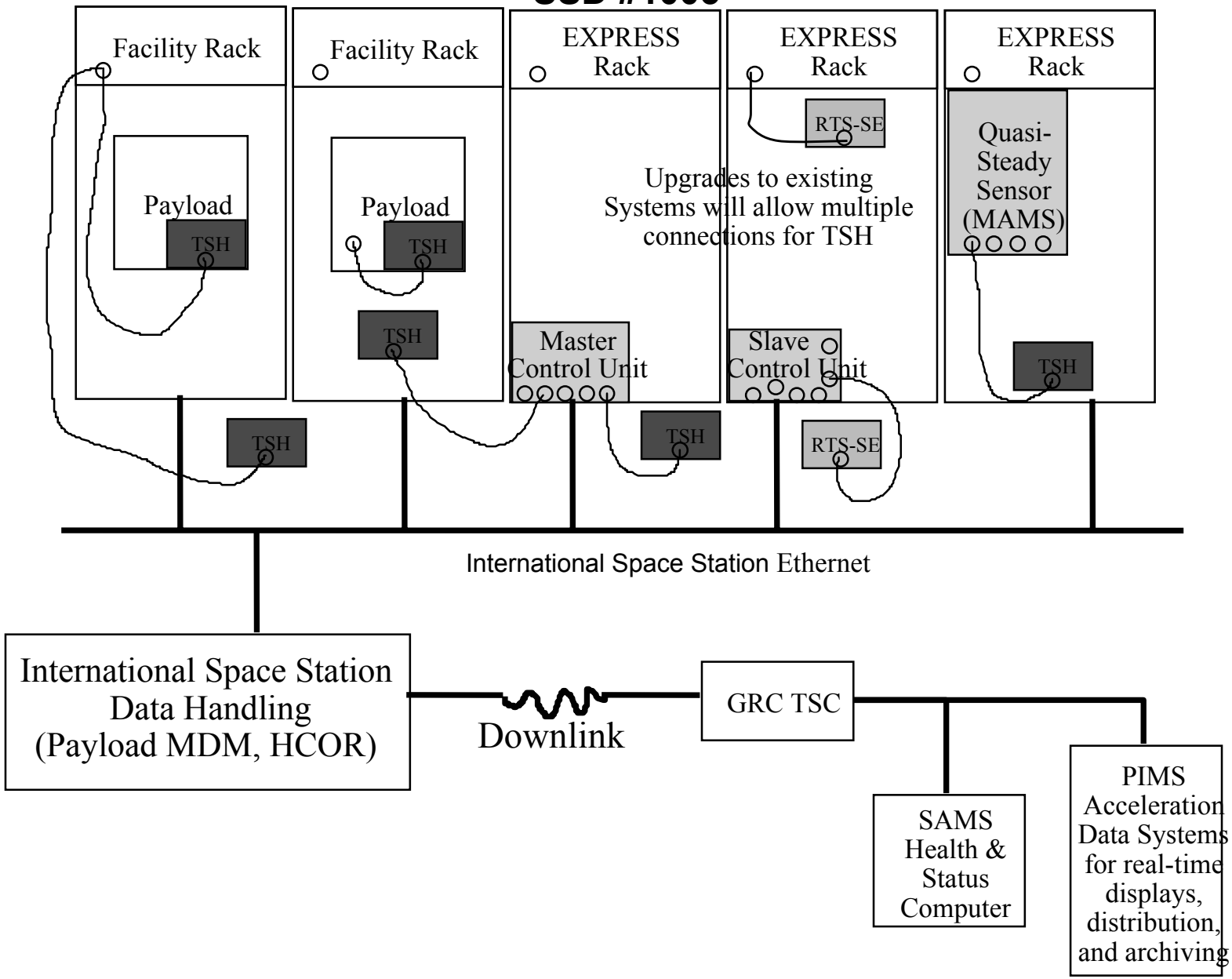
KC-135
Sensors: TSH, FOG
Control System: Control & Data Acquisition Unit



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

Example System Deployment

SSD #1005



Mission Criteria

- Current criteria established for Increment 5
- Definitions
  - Available is defined solely by the availability of the SAMS system. As long as the SAMS system is in working order, it is available, regardless of the state of the International Space Station/facility resources.
  - Total possible available time is the length of the reporting period.
  - For full success, each subsystem has to have availability of 85% or greater. Data collection for the predefined requests has to be 95% or greater. If there were additional requests, some need to have been performed.
- **Full Success**
  - SAMS International Space Station Systems will be available 85% of the total possible available time.
  - At least 95% of pre-negotiated data requests from specific customers will be met.
  - Generic requests for environment characterization or localized measurement will be performed.
- **Significant Success**
  - SAMS International Space Station Systems will be available 70% of the total possible available time.
  - At least 80% of pre-negotiated data requests from specific customers will be met.
- **Minimal Success**
  - SAMS International Space Station Systems will be available 50% of the total possible available time.
  - At least 70% of pre-negotiated data requests from specific customers will be met.

Mission Success Results
Increment 5 & 6

SAMS System	Available % (level of success)	Data Achieved %	Requests Met % (level of success)
SAMS ISS System	96.87%* (Full Success)	93.16%*	N/A
SE-F02	96.87% (Full Success)	93.16%	N/A
SE-F03	96.23% (Full Success)	92.52%	N/A
SE-F04	95.33% (Full Success)	90.83%	N/A
SE-F05	95.60% (Full Success)	91.10%	N/A
SE-F08 (SUBSA)	SAMS missed the first SUBSA run due to problems with the MSG rack and the SAMS flight software	SAMS missed the first SUBSA run due to problems with the MSG rack and the SAMS flight software	Percentage unavailable
SE-F08 (PFMI)	100% (Full Success)	100%	100% (Full Success)

*Conservative Estimate; based on highest continuously powered SE availability.

SAMS Traffic Model

Increments	2	4	5	7	8	8	9	9					
Flights	6A, STS-100	UF-1, STS-108	UF-2, STS-111	ULF1, STS-114	12A1, STS-116	13A, STS-117	13A1, STS-118	15A, STS-119	10A, STS-120	ULF2, STS-tbd	1J/A, STS-tbd	UF-3, STS-tbd	9A1, STS-tbd
System Components	4/19/2001	12/5/2001	6/5/2002	3/1/2003	6/5/2003	9/5/2003	10/9/2003	1/15/2004	2/19/2004	7/1/2004	10/7/2004	7/28/2005	10/28/2005
MAMS	UP - ER #1 - MD								OB - ER #1 - MD				
Interim Control Unit 173-F01	UP - ER #2-1	OB - ER #4-2							**OB - ER #4-2, end of life**	Refurbish or Replace?			
RTS Drawer 314-F01	UP - ER #1-1												
Electronics Enclosure 122-F02	UP - RTS Drawer 314-F01												
Fan MA17400-02	UP - RTS Drawer 314-F01												
RTS Drawer 314-F02	UP - ER #1-2												
Electronics Enclosure 122-F03	UP - RTS Drawer 314-F02												
Fan MA17400-03	UP - RTS Drawer 314-F02												
Embedded Electronics Enclosures													
Electronics Enclosure 122-F01													
Electronics Enclosure 122-F04			UP - ER #3										
Electronics Enclosure 122-F05	UP - ER #2, embedded								OB - ER #2, embedded				
Electronics Enclosure 122-F06			UP - MSG, work volume										
Electronics Enclosure 122-F07													
Sensors													
Sensor Enclosure 121-F02	UP - PIMS, in RTS Drawer 314-F01			DN - PIMS, in RTS Drawer 314-F01		UP - PIMS, Z-Panel below ER2						DN-PIMS, Z-Panel below ER2	
Sensor Enclosure 121-F03	UP - ARIS-ICE, Z-Panel below ER2		OB - PIMS, Z-Panel below ER2		DN - PIMS, Z-Panel below ER2		UP - PIMS, Z-Panel below ER1						DN - PIMS, Z-Panel below ER1
Sensor Enclosure 121-F04	UP - ARIS-ICE, Z-Panel below ER1		OB - PIMS, Z-Panel below ER1			DN - PIMS, Z-Panel below ER1		UP - MSG, work volume					DN - MSG, work volume
Sensor Enclosure 121-F05	UP - ARIS-ICE, ER2 light tray		OB - PIMS, ER2 light tray				DN - PIMS, ER2 light tray			UP - PIMS, ER2 light tray			
Sensor Enclosure 121-F06	UP - PCS, Test Section		DN - PCS, Test Section		UP - PCS, Test Section				OB - PCS, Test Section	OB - PIMS, in RTS Drawer 314-F01	DN - PIMS, in RTS Drawer 314-F01	UP-PIMS, in RTS Drawer 314-F01	
Sensor Enclosure 121-F07				UP - PIMS, in RTS Drawer 314-F01						DN - PIMS, in RTS Drawer 314-F01			UP-PIMS, Z-Panel below ER1
Sensor Enclosure 121-F08			UP - MSG, work volume					DN - MSG, work volume				UP-PIMS, Z-Panel below ER2	
Triaxial Sensor Head-ES -005										UP - FCF-CIR, TBD			
Triaxial Sensor Head-ES -006												UP - FCF-FIR, TBD	
Triaxial Sensor Head-ES -007													
Triaxial Sensor Head-ES -008													UP-MSG, work volume

Customers - How to request SAMS.

How to request a sensor or system

- Fill out PIMS questionnaire

  http://pims.grc.nasa.gov/html/RequestDataPlots.html
- Get SAMS Agreement & Interface Definition Document (AIDD) for International Space Station

  Available on http://sams.grc.nasa.gov
- Fill out AIDD questionnaire
- 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 shuttle or International Space Station
- SAMS will provide a system based on the MOU and/or ICAD
  - Return to SAMS after use

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

For more information:

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