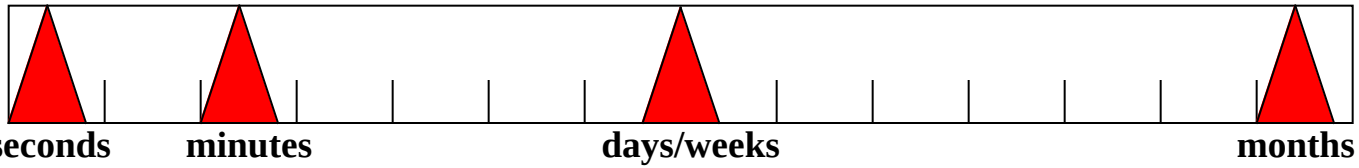
National Aeronautics and Space Administration **Marshall Space Flight Center**	**NASA Reduced-Gravity Carriers For Experiment Operations**	**Microgravity Research Program Office**

How Long Do You Need To Achieve Your Scientific Objectives?

Time →



Drop Towers/Drop Tubes
KC-135 Parabolic Flights
Balloons*

Sounding Rockets
Alternate Carriers*

Shuttle
Free Flyers
Alternate Carriers*

Space Station
Free Flyers

*In Development

Seconds

Drop Towers

- drop towers are typically used for experiments that require 2 to 5 seconds of free fall, or reduced gravity (weightlessness)

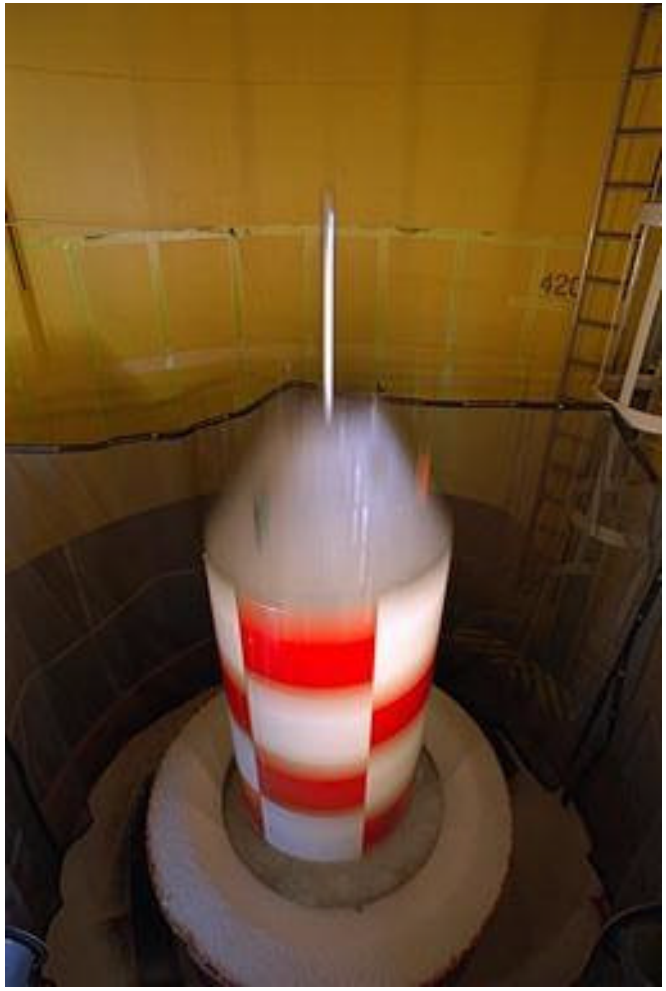
- the drop tower is an ideal research facility, especially for exploratory tests, as it is operated at a relatively low cost

- accelerometer data shows $\leq 10^{-4}$ g environment

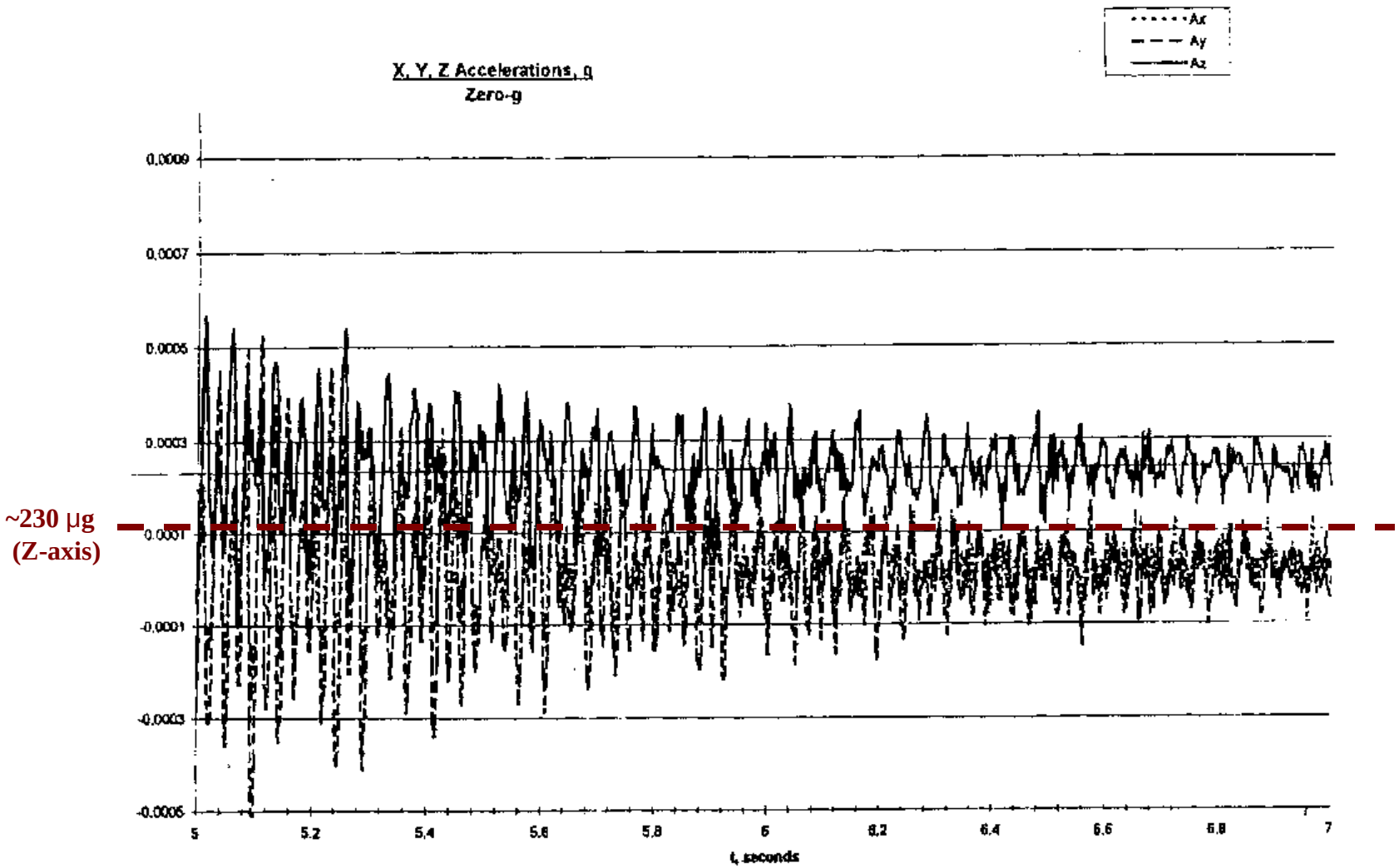
- two drop towers are operational at the Lewis Research Center (LeRC), providing 2.2 and 5.1 seconds of free fall, respectively

- for more information on NASA drop towers, try the URL

  http://zeta.lerc.nasa.gov/new/facility.htm



LeRC Drop Tower



LeRC Drop Tower Accelerometer Results (12/96)

Seconds

Drop Tubes

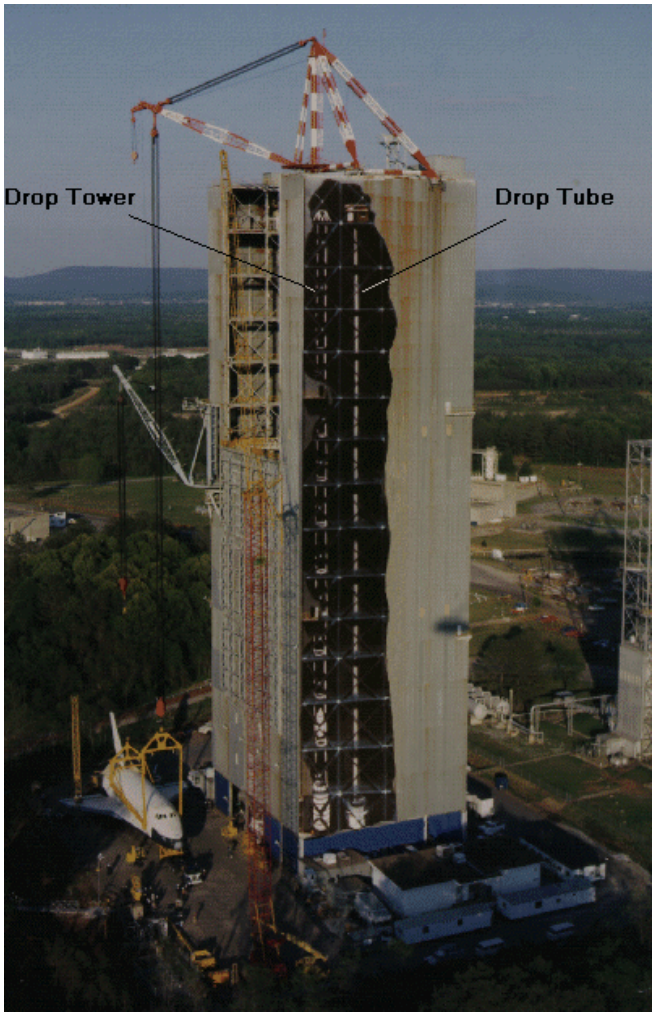
- a Drop Tube Facility of 105 meters in length is located at the NASA-Marshall Space Flight Center (MSFC) Dynamic Test Stand

- the Facility offers an extremely quiescent containerless environment, ideal for studies involving nucleation, solidification, and undercooling phenomena

- small samples with diameters up to 8 mm can be dropped

- minimal free-fall times of 4.6 seconds produce a reduced gravity environment for scientific observations, and vacuum levels of less than a billionth of an atmosphere are achievable

- for more information on the MSFC Drop Tube Facility, try the following URL:
  http://science.msfc.nasa.gov/ssl/msad/dtf/test/tube1.htm



MSFC Drop Tube Facility

Seconds

KC-135 Parabolic Flights

- the NASA-JSC KC-135 is a modified Boeing 707 (a four-engine turbojet) flown at NASA-JSC and NASA-LeRC

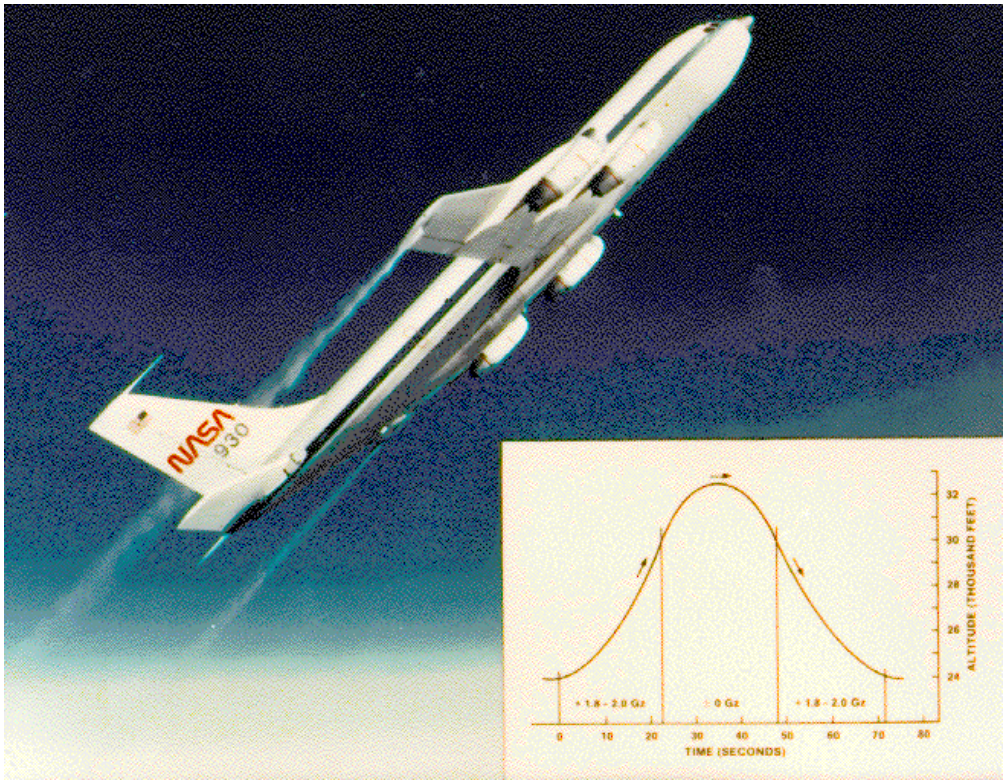
- for each flight day, the KC-135 achieves at least 40 parabolic flight trajectories (40 reduced gravity opportunities)

- NASA uses the KC-135 aircraft to fly parabolic trajectories to achieve a short-term reduced gravity environment to assess MRPO-managed scientific hardware/investigations

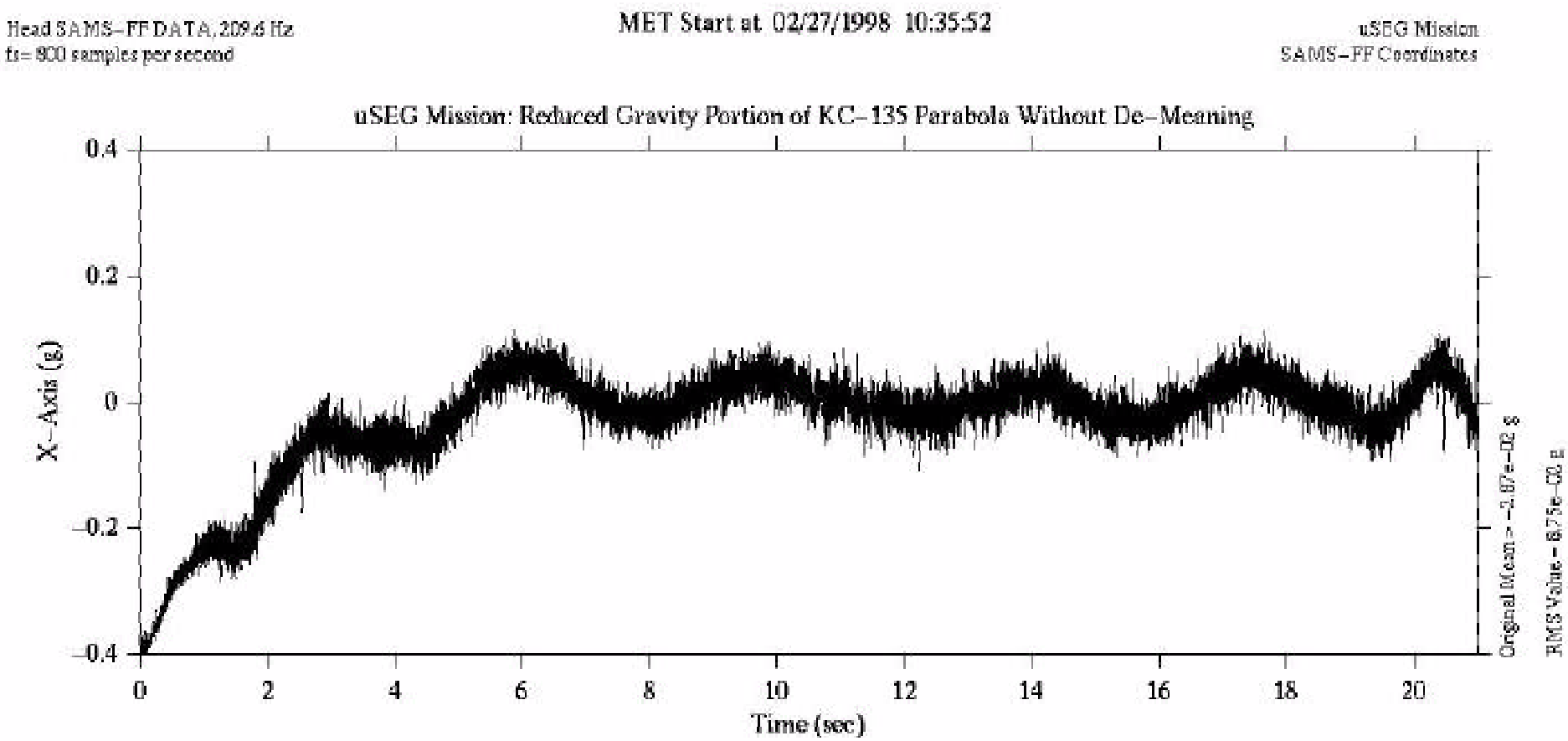
- each parabola produces approximately 20 to 25 seconds of a reduced gravity environment

- for more KC-135 information, try the URL

http://zeta.lerc.nasa.gov/kjenks/kc-135.htm



NASA KC-135 Aircraft in a Parabolic Trajectory



Acceleration Data During KC-135 Parabolic Flight

Seconds

Reduced Gravity Balloon Development

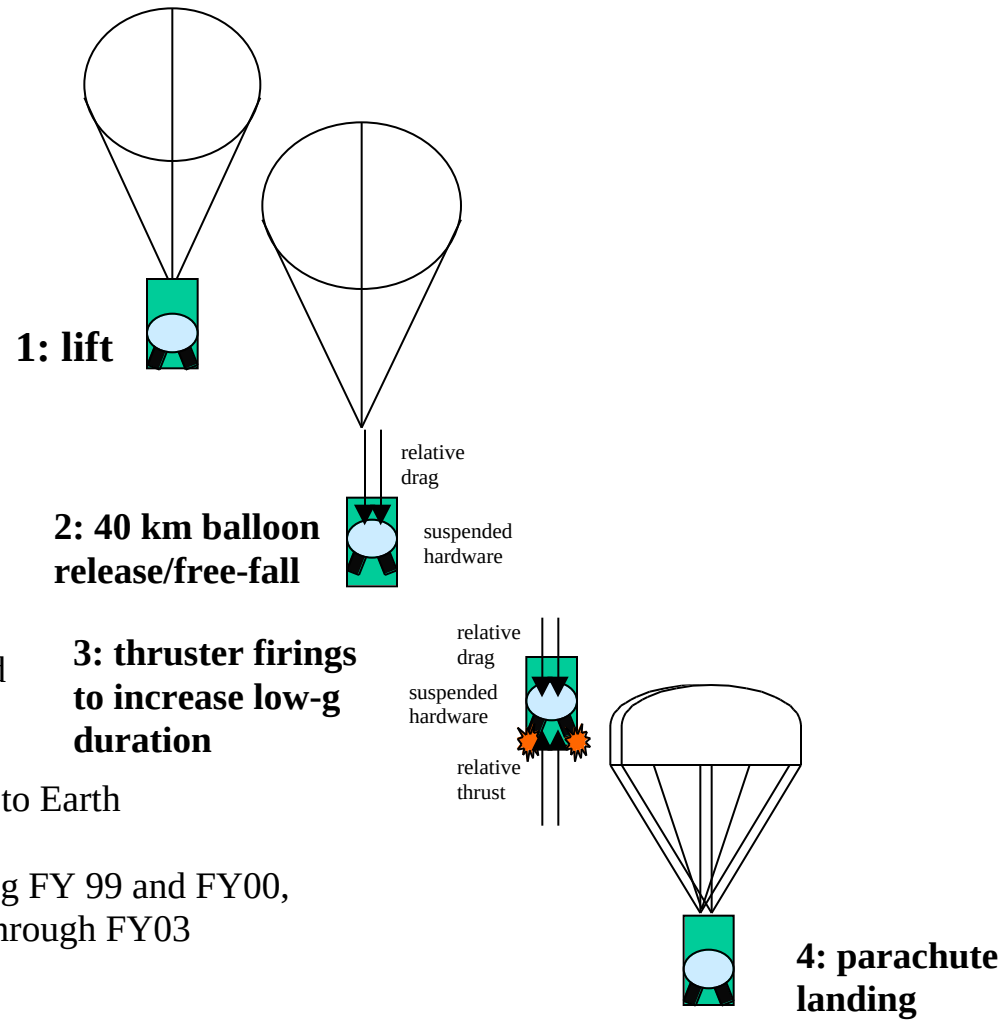
- NASA-MSFC is currently investigating the possibility of utilizing a thruster-equipped rocket-shaped drop capsule released from a NASA balloon to obtain a reduced gravity environment for MRPO-supported experiments

- empirical studies have shown that a rocket-shaped capsule dropped from a 40 km height (131,000 feet) will provide ~20 seconds of 10^{-3} g acceleration environment

- further studies revealed that when a rocket-shaped capsule is equipped with thrusters to counteract atmospheric drag effects on the released capsule, the acceleration environment within the capsule is expected to improve to ~10^{-6} g for ~50 seconds

- a parachute is deployed to bring the experiment back to Earth

- development of this carrier is expected to occur during FY 99 and FY00, with flight opportunities currently budgeted for FY00 through FY03



Minutes

Sounding Rockets

- NASA currently uses 14 different sounding rockets, ranging from the single-stage Super Arcas to the four-stage Black Brant XII

- these rockets can carry payloads of various weights to altitudes from 30 miles (48 km) to more than 800 miles (1,287 km)

- the overall time in a weightless environment is brief, dependent on the rocket's performance capabilities

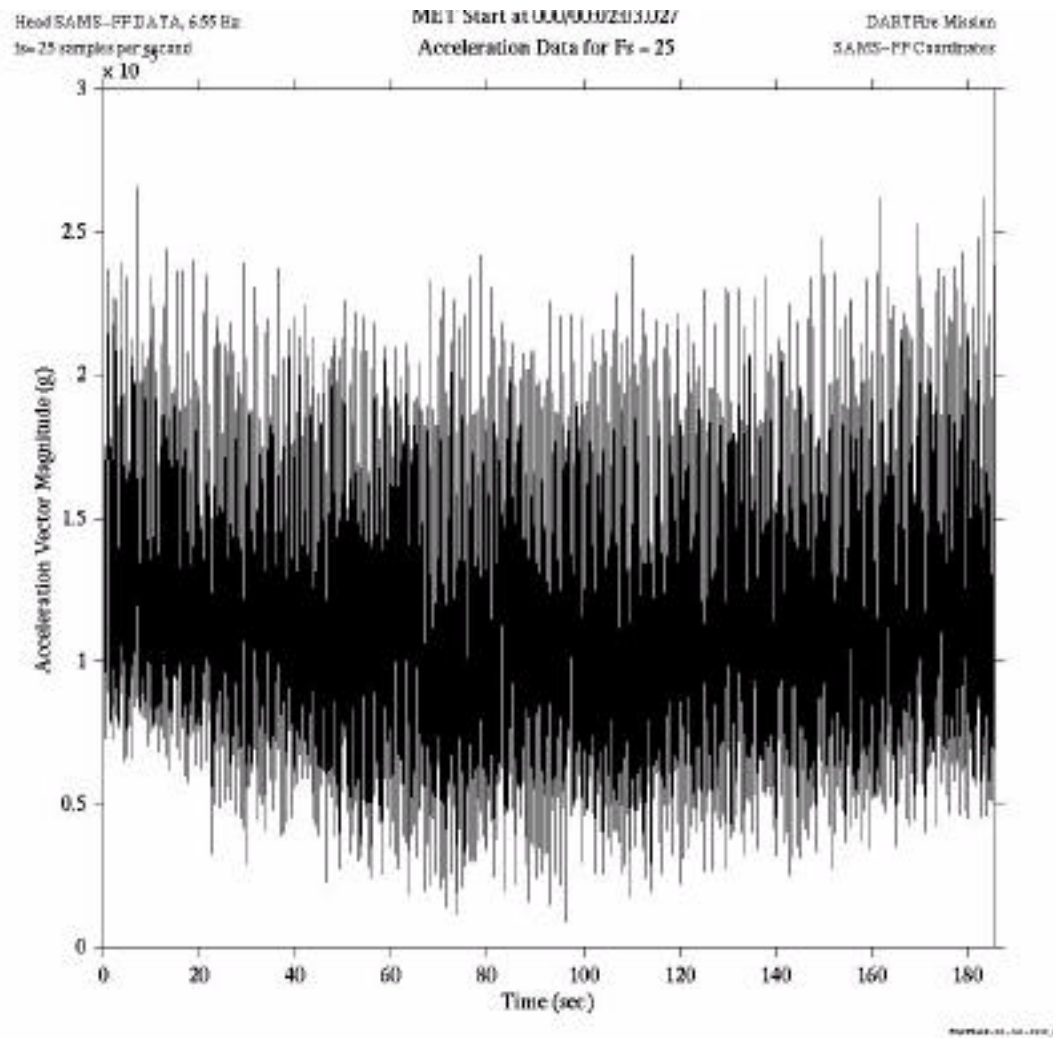
- the Black Brant IX sounding rocket provides approximately seven minutes of a reduced gravity environment

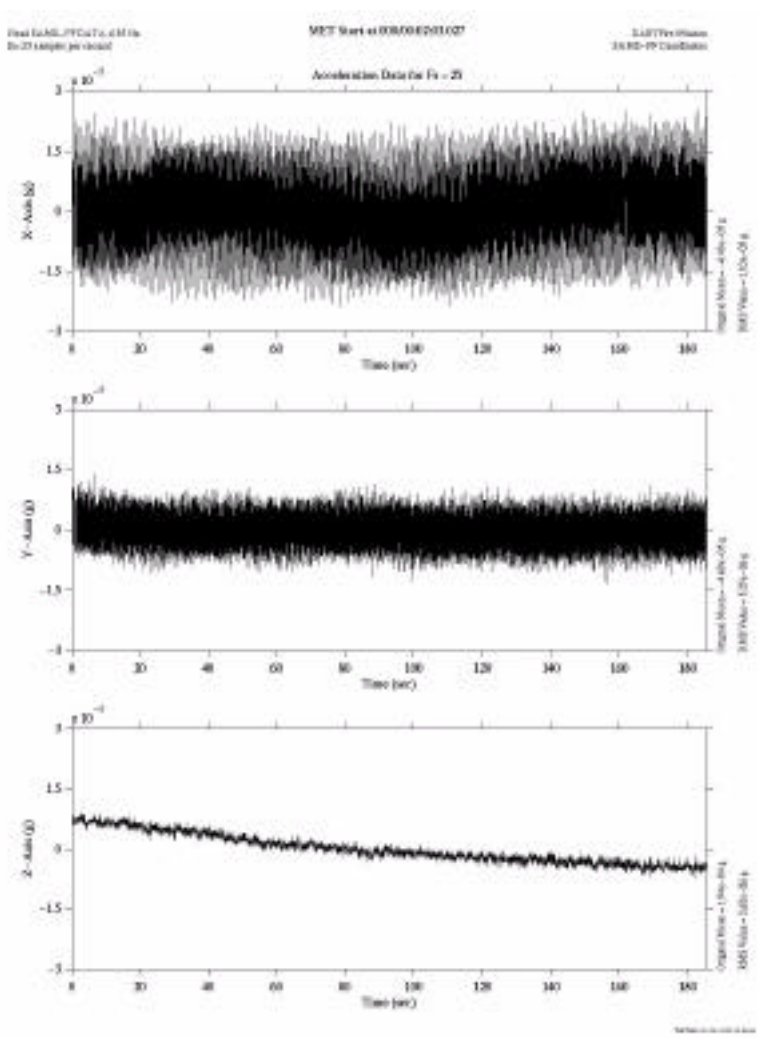
- low cost, with the ability to recover and refly instruments

- for more info on sounding rockets, try this URL:

  http://www.wff.nasa.gov/~web/sndroc_pics.html

Black Brant IX Sounding Rocket





SAMS Free Flyer Acceleration Data, 9/97 DARTFire Sounding Rocket Flight (10^{-5} g Magnitude)

Days/Weeks

Space Shuttle

Shuttle Flight Operations

- the Space Shuttle has a vast history of flying g-sensitive experiments into low-Earth orbit, ranging from a few days to over two weeks in duration

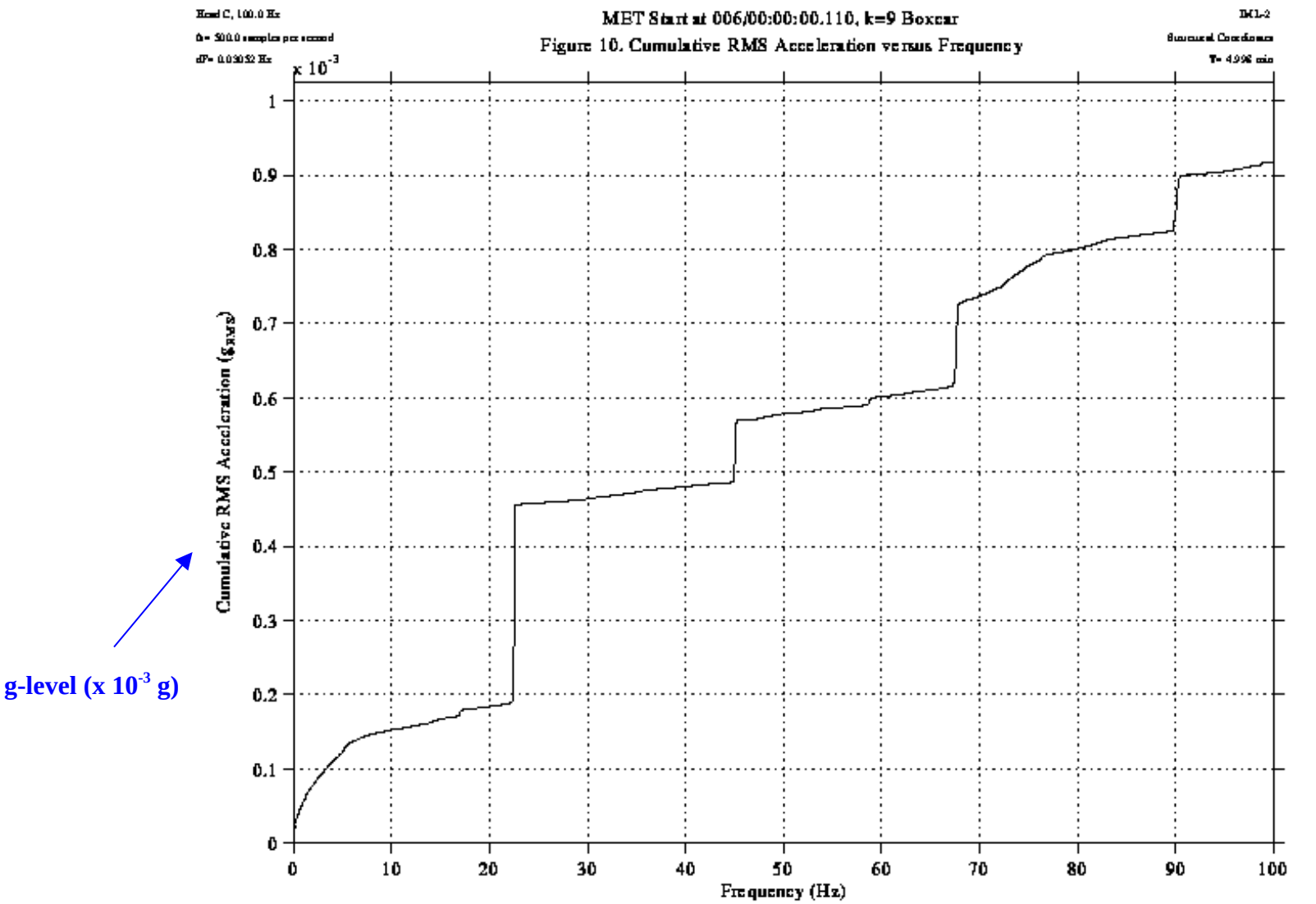
- before experiment flight hardware flies on the Space Shuttle it is generally taken on board NASA's KC-135 and tested under parabolic flight trajectory conditions to determine the effects of reduced gravity on the experiment

- possible locations for flying MRPO-sponsored experiments include:

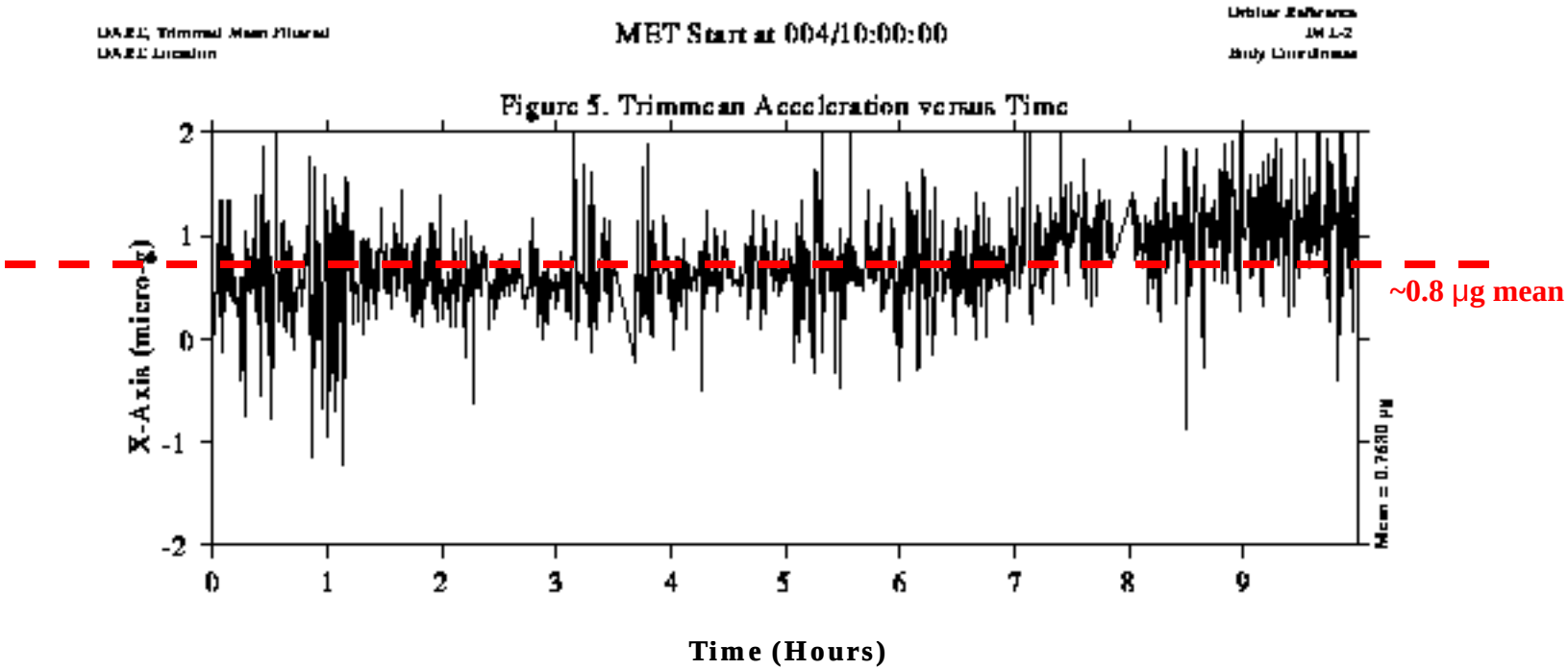
  → middeck
  → Get-Away Special (GAS) canister
  → MPESS carrier
  → SpaceHab

- much data has been obtained to characterize the on-board acceleration environment of the Shuttle in a range of frequency spectrums; for more info, click on this URL:

http://www.lerc.nasa.gov/Other_Groups/MMAP/PIMS/pims.html



SAMS Accelerometer Data, STS-65 Shuttle Flight (0-100 Hz Frequency Regime)



OARE Accelerometer Data, X-Body Axis, STS-65 Shuttle Flight (<< 1 Hz Frequency Regime)

Days/Weeks

Free Flyers

- Goddard Space Flight Center manages the series of Shuttle-deployed **Spartan satellites** (the non-retrievable Spartan Lite, the Spartan 250, and the Spartan 400)

- **Spartan 250** was designed for a deploy/retrieval period of 2-14 days, with a payload mass not to exceed 3000 lbs with minimal on-board power supply (2 on-board batteries)

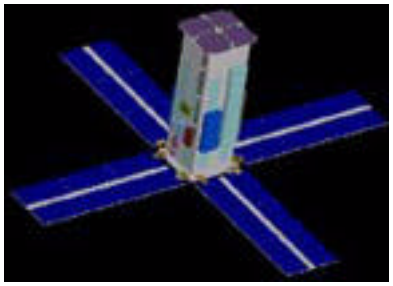
- the other two Spartan satellites are designed for a much longer duration in space (**Spartan Lite**: 3-12 month on-orbit lifetime, **Spartan 400**: 12 month on-orbit lifetime)

- general Spartan characteristics:

Carrier Type	Duration	Payload Weight	Power
Spartan Lite	3-12 months	100 lbs	100 W
Spartan 250	2-14 days	3000 lbs	18 kWh
Spartan 400	12 months	2000 lbs	250 W

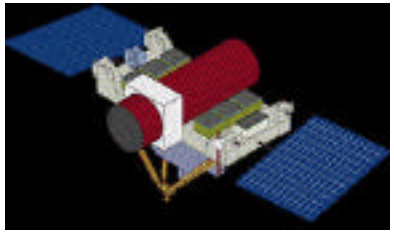
- for more information regarding Spartan satellites, go to this URL:

  http://spartans.gsfc.nasa.gov



Spartan Lite Free Flyer Satellite

Spartan 250 Free Flyer Satellite



Spartan 400 Free Flyer Satellite

Days/Weeks

Free Flyers

- the European Space Agency (ESA) designed and built the **European Retrievable Carrier (EURECA)** satellite to be used as an automated carrier system deployed and retrieved by the Shuttle

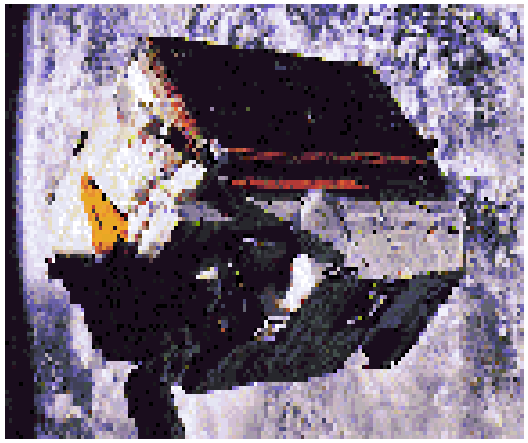
- the EURECA carrier is designed as a long duration space vehicle, able to provide adequate power, thermal control, and data transmitting to/from its microgravity payload complement for a number of weeks

- during its free flying mode the EURECA is operated and controlled at ESA's Control Center in Germany

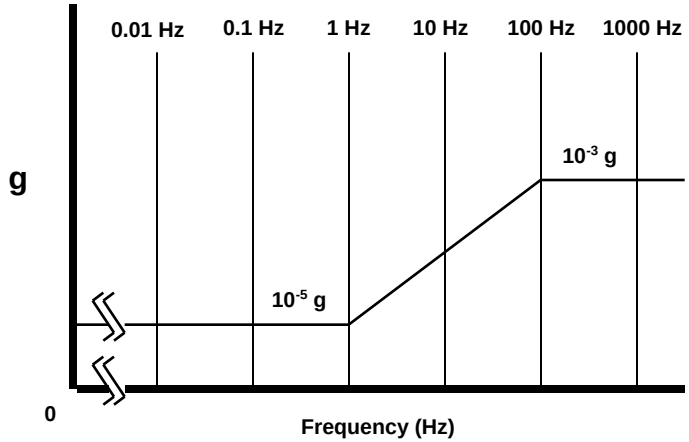
- EURECA successfully flew its maiden flight from July 1992 (deployed on STS-46) to July 1993 (retrieved on STS-57)

- for more information on the EURECA, try this URL:

http://esapub.esrin.esa.it/bulletin/bullet91/b91wimm.htm



EURECA Free Flyer Satellite



EURECA Microgravity Design Specifications

Table 1. Eureca on-board characteristics

Total spacecraft mass:	~4500 kg
Payload mass:	1000 kg
Payload power:	1000 W average, 1.5 kW peak
Orbit control:	hot gas system, Earth pointing mode
Orbit inclination:	28.5 or 51.6° depending on Shuttle mission
Orbit altitude:	440 to 600 km, altitude and eccentricity adjustable within fuel budget constraints
Attitude control:	hot or cold gas system with Sun and Earth sensors, gyros, accelerometers
Attitude: Sun inertial pointing: (capability for att. offset [roll around Sun vector] by bias TC)	± 1° (3 sigma), (actual performance during 1st flight ± 0.45^0)
Attitude measurement accuracy:	± 0.25° (3 sigma)
Microgravity:	$<10^{-5}$ g for f <1 Hz linear for 1 Hz< f <100 Hz $<10^{-3}$ g for f >100 Hz
ESP dimensions:	70 x 70 cm^2
Orbital operational temperature:	0 to 40°C (active payload cooling/heating capability)
Orbital non-operational temperature:	-10 to 40°C
On-board data storage capacity:	13 Mbytes (11.3 for payload, 1.7 for housekeeping)
Ops. pre-programming in on-board master schedule:	up to 60 h ahead
Packet telemetry:	payload, housekeeping (system and payload), event messages
Packet telecommand:	high/low level commanding as desired
Flight application programmes:	generic infrastructure for subsystems and payload operations control, command expansions and fault detection, isolation and recovery

Months

International Space Station (ISS)

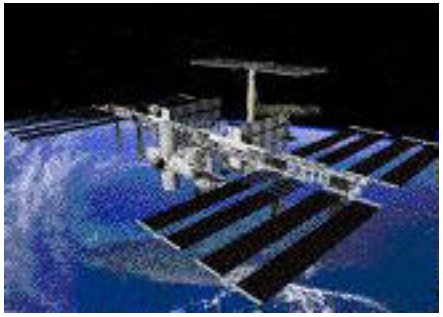
- the ISS, expected to begin construction with the launching of the first major component in the fall of 1999 (Functional Cargo Block), will be completed by 2004

- payload operations aboard the ISS will commence with the First Utilization Flight (UF-1), scheduled for launch in April of 2000

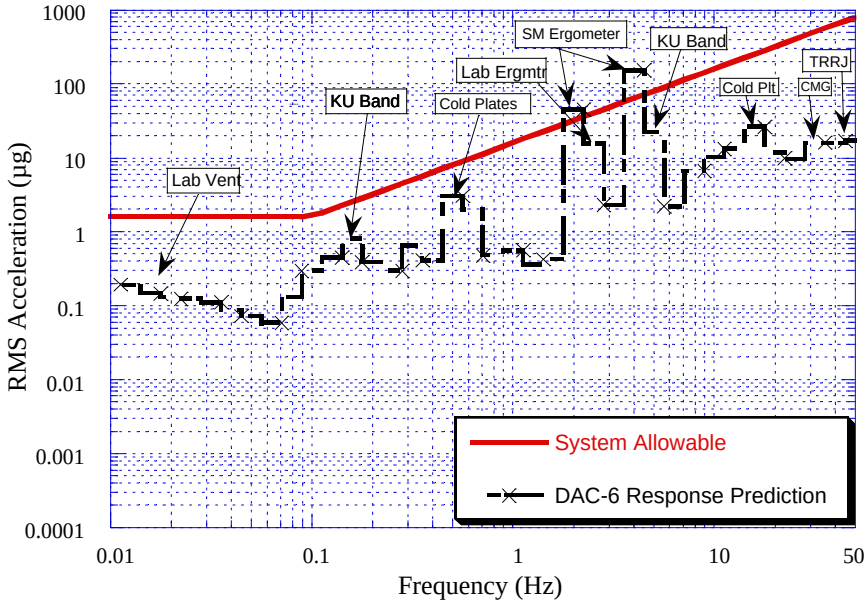
- the ISS will be comprised of four major elements where payload operations will take place:
  - → United States module
  - → European module
  - → Russian module
  - → Japanese module

- the ISS is designed to meet the acceleration environment specifications that were developed by the microgravity user community

- for more information on the ISS, try this URL:
  http://station.nasa.gov/core.html



ISS Assembly Complete



Expected ISS Microgravity Environment

Months

Free Flyers

- of the available **Spartan** carriers, the **non-retrievable Spartan Lite** and the **retrievable Spartan 400** satellites are designed to remain on orbit for **up to twelve months**

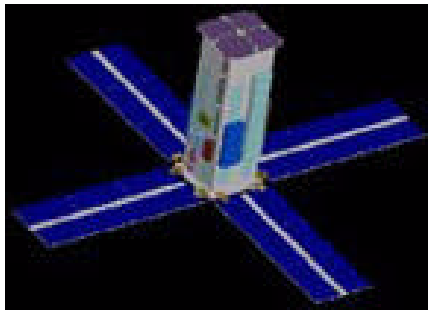
- the **EURECA** satellite is designed for a **six to nine month** operational stay in low Earth orbit

- **all three** carriers are **Shuttle-deployed**; currently, **none** of these three carriers are on the official NASA Shuttle Flight Manifest **BUT** each of these carriers are available for use by the microgravity community

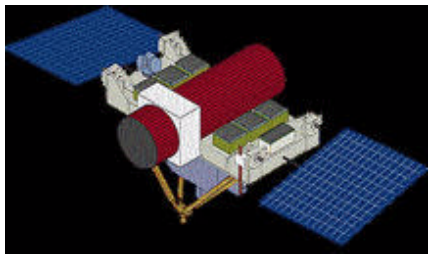
- information on these carriers are located at these URLs:

http://spartans.gsfc.nasa.gov

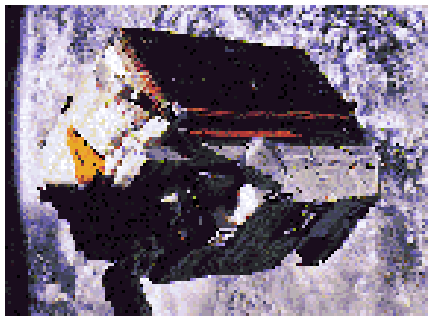
http://esapub.esrin.esa.it/bulletin/bullet91/b91wimm.htm



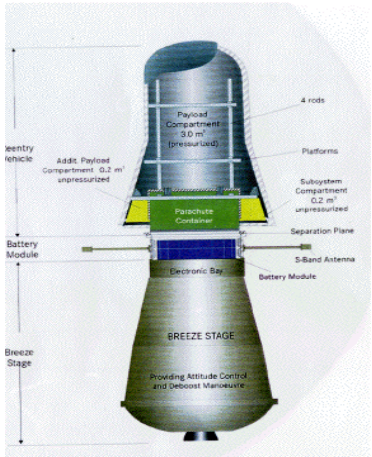
Spartan Lite Free Flyer Satellite



Spartan 400 Free Flyer Satellite



Eureca Free Flyer Satellite

Alternate Carriers (Developmental Stage)

Duration	Vehicle	Description	
Minutes	X-34	• Air-launched vehicle developed by Orbital Sciences Corporation as sub-orbital carrier • 1st powered flight scheduled for 8/99 • http://www.orbital.com/	
Minutes	Astroliner	• Air-launched vehicle developed by Kelly Space & Technology (KST) • 1st stage of flight suborbital • 1st test flight scheduled in 1998 • http://www.kellyspace.com/	
Days/Weeks	COMCAP	• International consortium developing turnkey system for microgravity payloads at <$40k/kg • touts <$10^{-5}$ g environment for long durations (5-20 days) • 1st US launch 2000-2001 timeframe • http://www.itaspace.com/