DRAFT R4

12 Nov 2003

Overview of OBPR Free Flyer System Concept

Ron Leung
NASA/GSFC Code 594

Free Flyer Research Workshop

December 2-3, 2003

Technical Contributions
Al Lieberman
NASA/GSFC Code 594

OBPR Free Flyer Theme

- Develop a dedicated Free Flying (unmanned) spaceborne research capability for OBPR
- Need for spacebased research capability (Biological and Physical) that is complementary to the Shuttle or ISS
- Research would utilize hazardous environments not encountered on Shuttle or ISS
- Mission duration, orbital parameters, etc driven by research needs
- Free Flyer Platforms address
  - Research requirements and needs
  - Technology development
  - Education and outreach
- Would build on extensive experience from
  - Biosatellite (1960), Bion/Foton, Lifesat (study), Skylab, STS, MIR and ISS

OBPR Free Flyer Technical Activity last 2 years

- 2002
  - Free Flyer ARC Workshop (June 2002)
    - OBPR Research Centers
    - NASA/GSFC
    - Research drivers for Free Flyer (FF)
    - Requirements
- 2003
  - 4 GSFC INTEGRATED MISSION DESIGN CENTER (IMDC) STUDIES
    - (January – August)
  - Preliminary Free Flyer presentation to NASA Headquarters (February)
    - M. Kicza & Directors
    - Authority to Proceed
  - Coordination meetings
    - Expendable Launch Vehicle (ELV) Office (HQ/KSC) (June)
    - Space Experiment Research & Processing Laboratory at KSC (June)
    - Utah Test & Training Range (UTTR) (July)
      - Conceptual Free Flyer Heavy recovery site

GSFC INTEGRATED MISSION DESIGN CENTER (IMDC) STUDIES

- GSFC IMDC Free Flyer Medium Study #1 (13 to 17 Jan 2003)
  - High Earth Orbit, one way/no return, beyond Van Allen Belts, 10-e5 G
- GSFC IMDC Free Flyer Heavy Study #2 (10 to 14 Feb 2003)
  - Low Earth Orbit Return, payload recovery, quiescence
- GSFC IMDC Free Flyer Heavy RV Study #3 (14 to 18 April 2003)
  - Follow-on to previous study (#2)
  - Concentrated on RV conceptual design and earth return
  - Low Earth Orbit Return, payload recovery, quiescence
  - Environmentally controlled RV payload volume
  - Provisions for live specimens and power through all mission phases
- GSFC IMDC Free Flyer Heavy Study #4 (4 to 7 August 2003)
  - Advanced System Concept Study

Free Flyer Expertise For Studies

- Science
  - ARC
    - Fundamental Biology
    - Fundamental Space Biology
    - Previous Free flyer Experience
    - Requirements
  - JSC
    - Biotechnology
  - MSFC
    - Physical Science
    - Material Science
  - JPL
    - Fundamental Physics
- Engineering
  - GSFC
    - Integrated OBPR Mission Free Flyer IMDC Studies
    - System & Subsystem S/C Engineers
  - JPL, LARC, ARC, MSFC, GRC
    - System & Subsystem Engineers

Free Flyer Assumptions & Goals

- Studies
  - reference experiments derived from FF workshop (June 2002)
  - developed mission & S/C concepts
  - concepts only, at this point, not a design baseline
  - open discussion and feedback sought from user community
  - subject to change as a result of this workshop
- Launch vehicle
  - assumed FFM & FFH requirements could be satisfied by Delta II for study
  - Proven reliable launch vehicle
  - reduces mission costs from assuming larger launch vehicle
- Lowest possible orbit/inclination to accomplish mission
  - reduces mission costs
- FFH Re-entry Vehicle terrestrial recovery (CONUS)
  - reduces mission/operational costs
- OBPR FFM & FFH spacecraft
  - similar copies in each class
  - assumed mass production techniques employed
  - reduces mission/operational costs

Free Flyer (FF)
Total Payload Reference Concept Capabilities

ITEM	FF Medium (FFM)	FF Heavy (FFH)	Secondary Payloads of Opportunity
Operational (days)	30 design, 60 goal	30 design, 60 goal	TBD (ex. hrs to days)
microG (g)	10-e5	10-e5	TBD
Orbit	Circ, 70000 km (12 Re), 28.5 deg incl	Circ, 550 km 40.5 deg incl	depends on primary payload
Mass (kg)	170 (1)	920 (1)	0 to 50
Volume (m3)	1.55 (2)	2.5 (2)	TBD(ex. 0.009 to 0.09)
Power (kw)	0.25	2	TBD(ex. 0.002 to 0.060)
Thermal (deg c)	25	20	TBD(ex. -23 to -12)]
Data (kbps)	58	313	TBD (ex. 4 to 40)

(1) Science payload mass includes payload structure mass
(2) Science payload volume includes payload structure volume

FFM Reference Payload Requirements

Provided by OBPR Research Centers
Derived from Research Workshop June 2002

Payload	Mass	Data	Volume	Power	Operational	MicroG	Orbit
PS1 Biosentinel Devices	5kg*	1Mb/day for 10 days	m^3*	50W*	30 - 60 days	10^{-3}	HEO
PS4 Diffusion Measurements	100kg	High quality video - TBD frequency	0.5 m^3	75W	21 days duration	10^{-4}	NS
PS12 Microgravity Crystal Growth	40kg	Video frames + control/housekeeping data	0.5 m^3	20W	1-6 months duration	10^{-5}	NS
FB2 Yeast Radiation	26kg	Low rate	0.5 m^3	100W	30+ days	10^{-3}	HEO
Total Payload	**170kg**	**Video, command/control, housekeeping**	**1.55 m^3**	**250W**	**60 days**	**10^{-5} g**	**HEO**

FFM Requirements

Mission Driving

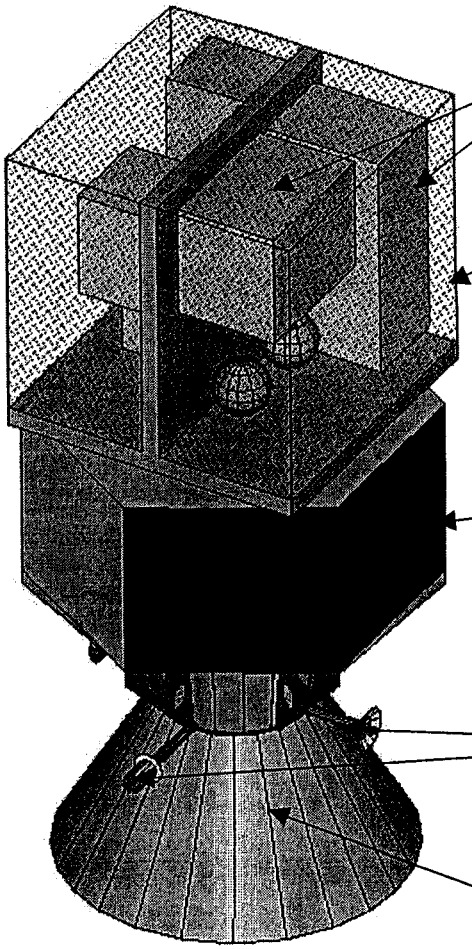
- Provide payload with exposure to Galactic Cosmic Rays (GCR's) as would be experienced in interplanetary space.
- Capable of maintaining a micro-gravity environment (10^{-5} g) once payload is delivered to orbit.
- Provide a mid-sized platform (<1000 kg) on which to fly 4 representative experiments to the GCR and microgravity environment.
- Provide late access on launch pad (L – a few hours) to load biological samples and materials as required.

Mission Derived Requirements/Parameters

- Orbit :
  - No inclination requirement, May be elliptical or circular
- Spacecraft:
  - Power, Communication, Attitude Control, C&DH, Thermal Control
  - Experiment Vent and Vacuum ports

FFM Mission

Total Vehicle mass:
1091 kg
Payload Module mass:
170 kg
Launch Vehicle:
Delta II-H
Orbit:
HEO (≈ 70,000 km), circular @ 28.5°
Continuous Quiescence:
Target is ≤ 10^{-5}G
Data Collection:
Telemetric
(no spacecraft return)



Experiments

Optional pressurized Payload Module
(1.6 x 1.6 x 1.6m Volume)

Spacecraft (S/C)
Body-mounted solar cells
Flight Computer
Attitude Control System (ACS)
C&DH
Consumables for ECLSS
Power System

Communications Antennas

Kick motor (inside)
Star 30 BP

FF Medium Summary

- 4 reference payloads-Mixed Physical & Biological payloads
  - total mass 170kg, volume 1.55 m3
- Payloads are not returned to the Earth
- 12 Re x 28.5 deg inclination circular orbit – GCR exposure, 10-5 micro g on orbit
- Mission Life-30 day design, 60 day goal
- Late access to payload on launch pad (biological samples & materials)
- Attitude Control System-Inertial Pointing s/c
- Mechanical-modular concept, aluminum, heritage s/c fixtures, brackets and fittings, 1.6x1.6x1.6 m3 total payload volume
- Data- Average data rate 58 kbps, s band telemetry at 2 Mbps, s band commanding at 2 kbps, 2 days of data storage 10 Gbits
- Thermal- common cold plate, payloads maintained at 25 deg c

FFH Reference Payload Requirements

Payload	Mass (kg)	Data	Volume	Power	Operational	MicroG	Orbit
PS06 High Temperature Materials Processing	120	Low rate; some video frames, 1 kbps	0.5m^3	300 - 500W ?	60 days	10^{-7}*	N/S
SPD2 Commercial Protein Crystal Growth	32	High quality video - TBD frequency, 1 Gb/day	1 MDLE (0.054m^3)	128W	50 d	$\leq 10^{-4}$	N/S
PS03 ISLES	300	7 channels x 20 Hz, downlink 1/day, 2.2kbps	~1m^3	50 - 200W	60 d, needs vent for LHe	$\leq 10^{-5}$	N/S
SPD6 Vulcan	128	Housekeeping data + uplink of commands, 1 kbps	4 MDLE (0.22m^3)	350 - 900W	$\geq$ 10 d, needs vacuum	$\leq 10^{-4}$	N/S
FB03 Mice Radiation	300	Low rate data, 1 kbps (video?), 3.6 Mbps for 80 min per day	10 MDLE (0.54m^3)	400W	30 days	10^{-3}	N/S
PS02 3D Tissue Model Radiation	140	<1Mb/day + video of 3.6 Mbps for 30 min every 3rd day	2 MDLE (0.11 m^3)	325 W	60 d	10^{-3}	N/S?
Total Payload*	**1020**		**~2.5 m^3**	**~2 kW OAP**	**60 days**	**10^{-5}g nominal *10-7g requested**	**LEO, 40°**

* Study results show </= 920 kg capability (payload structure included)

FFH Driving Mission Requirements

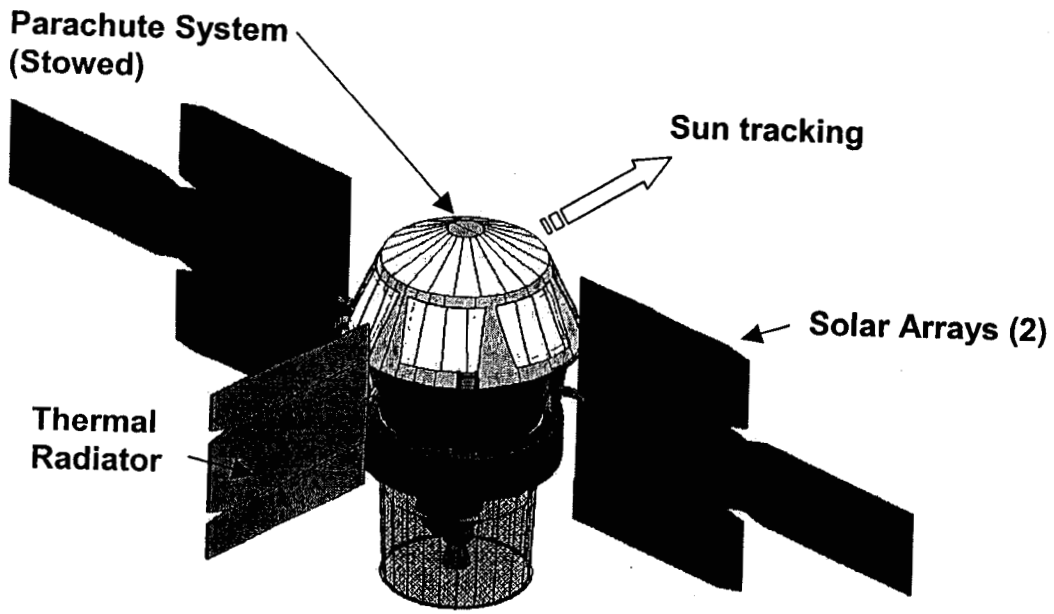
- Provide a large (payload ~1000 kg) on-orbit laboratory on which to fly 6 representative experiment payloads to a microgravity environment in a LEO orbit.
- Capable of maintaining a micro-gravity environment (10^{-5} g requirement, 10^{-7} g goal) once payload is delivered to orbit.
- Provide payload re-entry capability to CONUS, reliability of hitting target landing area of 99.95%.
- Provide late access on launch pad (L – a few hours) to load biological samples and materials.
- Maintain the primary launch and re-entry load vector in the same direction
- Maintain G-load throughout mission to less than 10 g.
- Maintain payload environment for ~12 hours after beginning of re-entry .

FFH Requirements
Mission Parameters

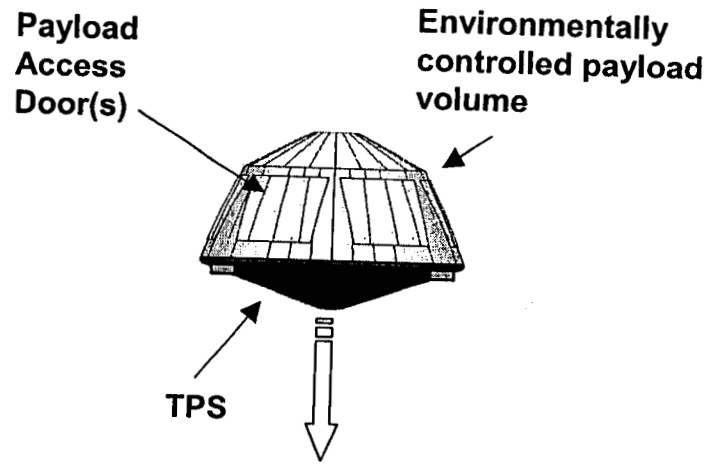
- Orbit requirements:
  - Inclination requirement driven only by landing range location (CONUS/UTTR assumed)
  - LEO desired to allow large mass to orbit
  - Must be suitable for maintenance of microgravity level, altitude high enough to minimize aerodrag
- Spacecraft (SC) Driving Requirements
  - Redundancy required to reliably hit the target landing area
  - Design must maintain micro-g environment
- Re-entry Vehicle (RV)
  - Provide thermal protection for re-entry
  - House all payloads, ECLSS, support systems, parachute system
  - Provide vent and vacuum ports for payloads
  - Provide means for vehicle location during re-entry and after landing
  - Provide hatches for access on pad
  - Provide resources and thermal control for up to 12 hours after spacecraft separation
- Launch Vehicle
  - Delta II desired to keep cost down
  - Provide late access to payloads on launch pad
- Landing Site
  - Continental United Stated (CONUS) desired

FFH Mission

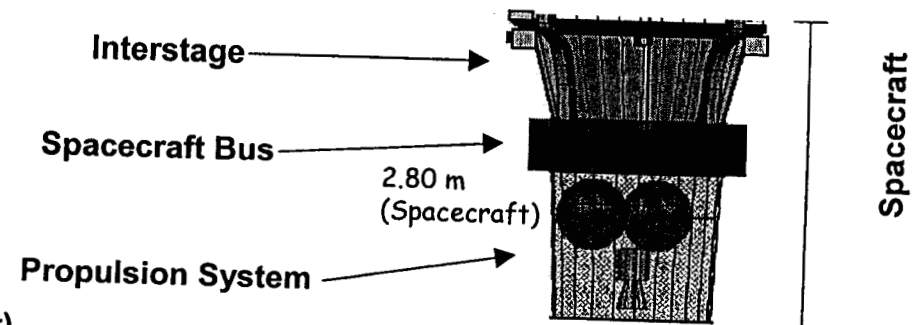
Vehicle On-orbit Configuration



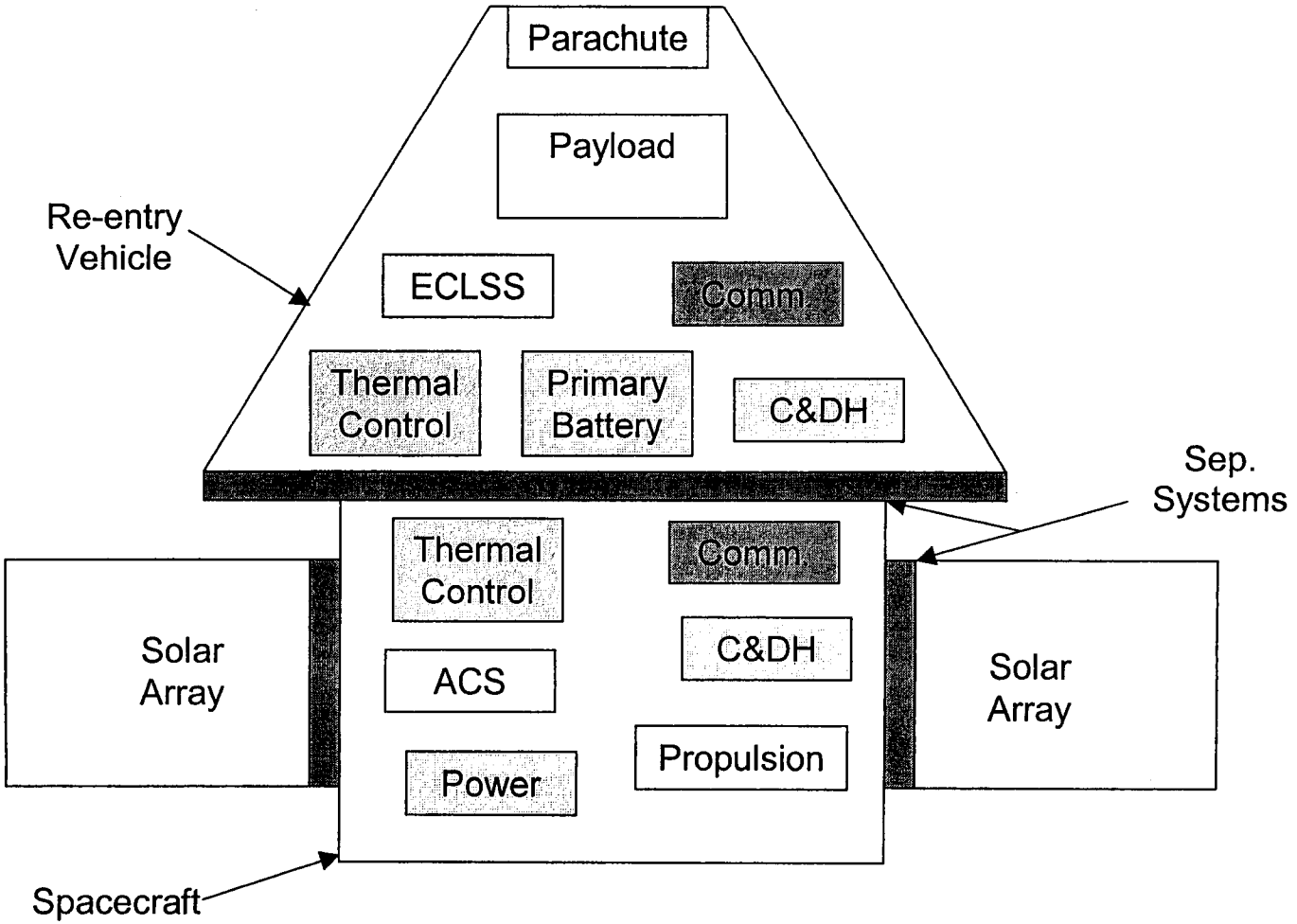
Recovery Vehicle (RV)



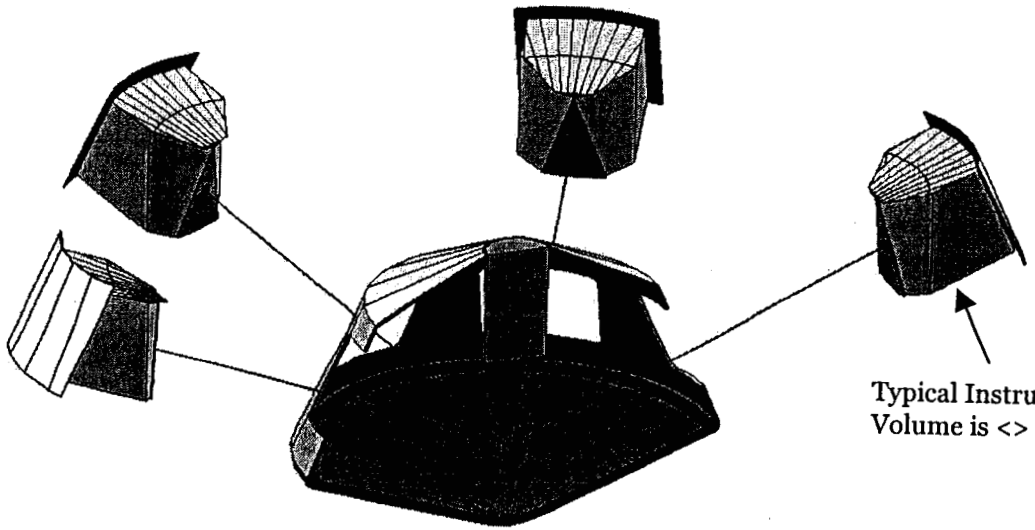
Total Vehicle mass: 3453 kg
RV mass: 1963.9 kg
Payload module mass 921 kg
RV Volume: 4.3 m^3
Payload Volume : 2.5 m3
RV Diameter: 2.44m
Launch Vehicle: Delta II Heavy
Orbit: 550 km circular @ 40.5°inclination
Recovery: Utah Test & Training Range (concept)



FFH BLOCK DIAGRAM CONCEPT



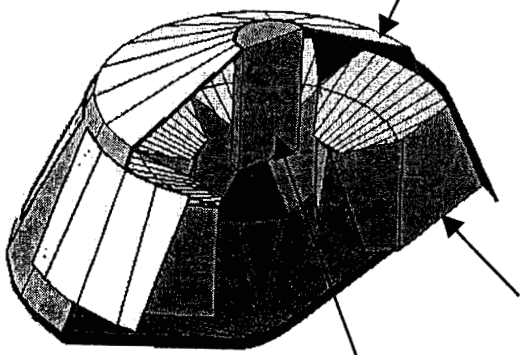
FFH Aeroshell & Payload Modular Concept



Typical Instrument Module
Volume is <> .3 m³

Note! Total inside usable Volume = 4.3 m³
total instrument volume = 2.5 m³
total volume shown here = 1.8 m³

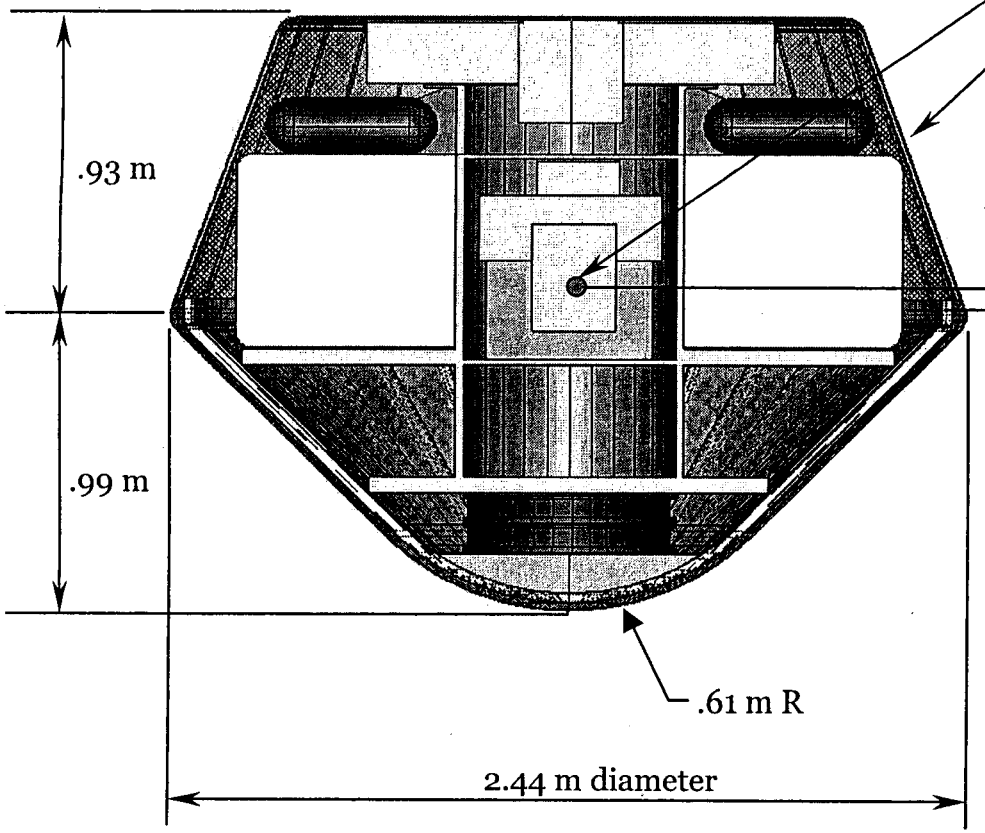
Cut-a-way view of Aero Shell housing

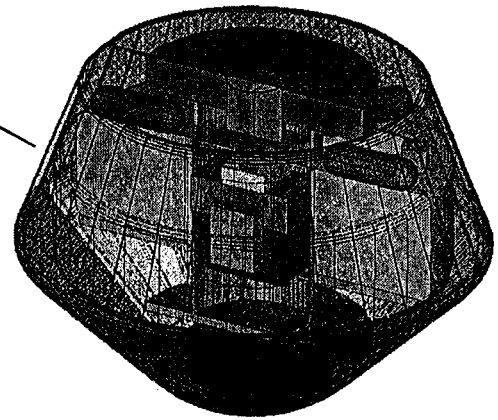


Instrument volume mounted on a Track (not shown). Remove the Access Panel, then slide out the Instrument.

Volume set-a-side for the Parachute Assembly

FFH Aeroshell & Toroidal Payload Concept





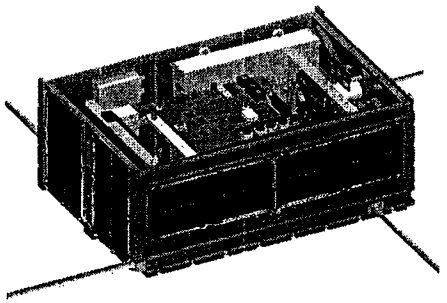
Volume of Aeroshell, For Reference only

FFH Heavy Summary

- 6 reference payloads-Mixed Physical & Biological payloads
  - –total mass </=920 kg (structure included), volume 2.5 m3
- Payloads are returned to the Earth
- 550 km x 40 deg Circular orbit – 10-5 micro g on orbit
- Mission Life- 60 days design, 90 days goal
- Late access to payload on launchpad (biological samples & materials)
- Attitude Control System-Inertial Pointing s/c
- RV Mechanical-modular or toroidal payload concept, aluminum honeycomb aeroshell, 2.5 m3 total payload volume
- Data- Average data rate 313 kbps, x band telemetry at 20 Mbps, s band commanding at 2 kbps, 1.5 days of data storage 40 Gbits
- Thermal- common cold plate, payloads maintained at 20 deg c, TPS for re-entry aeroshell
- ECLSS- Provides atmospheric consituents, revitalization, monitoring, total pressure control, sensible heat control

Secondary Payloads of Opportunity

- Third class of flight opportunity under Free Flyer Program
  - 1 kg to 50 kg
- Small, self-contained OBPR research payloads
  - Technology demonstration/development
  - Education
  - Public Outreach



- High level concept only at this time
- Accommodated on other primary missions with excess margins
  - FFM, FFH and other possible NASA/DOD/commercial/international missions
  - Must meet mass, volume, power, data etc margins allotted by primary
- Assumed
  - No interference with primary mission
  - Accommodate orbital parameters of primary mission
  - Launch schedule of primary is sacrosanct
- Examples
  - Nanosatellites
  - Picosatellites

Free Flyer Study Derived Constraints FFM, FFH

- Dollars
  - Attempt to keep total program costs constrained (e.g. Launch Vehicle)
- Mass Margin (over Delta Launch Vehicle capability)
  - FF Medium [non return,70,000km (12 Re)] 25%
  - FFH Heavy (baseline, return, 550 km) 34%
- Volume
  - FF Medium & FFH Heavy have adequate volume for reference payload
    - Modular Accommodation
    - Late Access
- Other
  - FFH
    - Landing Site, S/C launch pad accessibility, power, propulsion, thermal

Workshop and Requirements

- Expect more detailed scientific requirements as a result of this workshop
- Please review the requirement matrices for Splinter Session 2 in which you will provide your proposed experimental scientific requirements for
  - FFM Spacecraft
  - FFH Spacecraft
  - Secondary Payloads of Opportunity
- Future studies will be based on these requirements

Scientific Requirements Matrix

			Mission Duration (months)	Sample Recovery (Yes / No) Why?	Spacecraft MicroGrav (DC, Vibration) Why?	Is inflight variable G required? If so, what level?	Orbit (e.g., LEO, HEO, other) Why?
		EXAMPLE:	1-6	No	10E-5 to 10E-6 for 10 days; 15 days of .3 to .5 Gs	15 days of .3 to .5 Gs - provide profile and why?(see previous column)	Desire GEO; both LEO and HEO acceptable
Research Outcome 1		***Understand how living systems respond to continuous ultra-low gravity levels over***					
Research area 1		Determine molecular mechanisms	1-6				
Research area 2		Determine g sensing threshold	1-6				
Research Outcome 2		***Understand the responses of pathogenic organisms and their hosts to spaceflight***					
Research area 1		Determine virulence					

Formulation Activities needed FY04,FY05

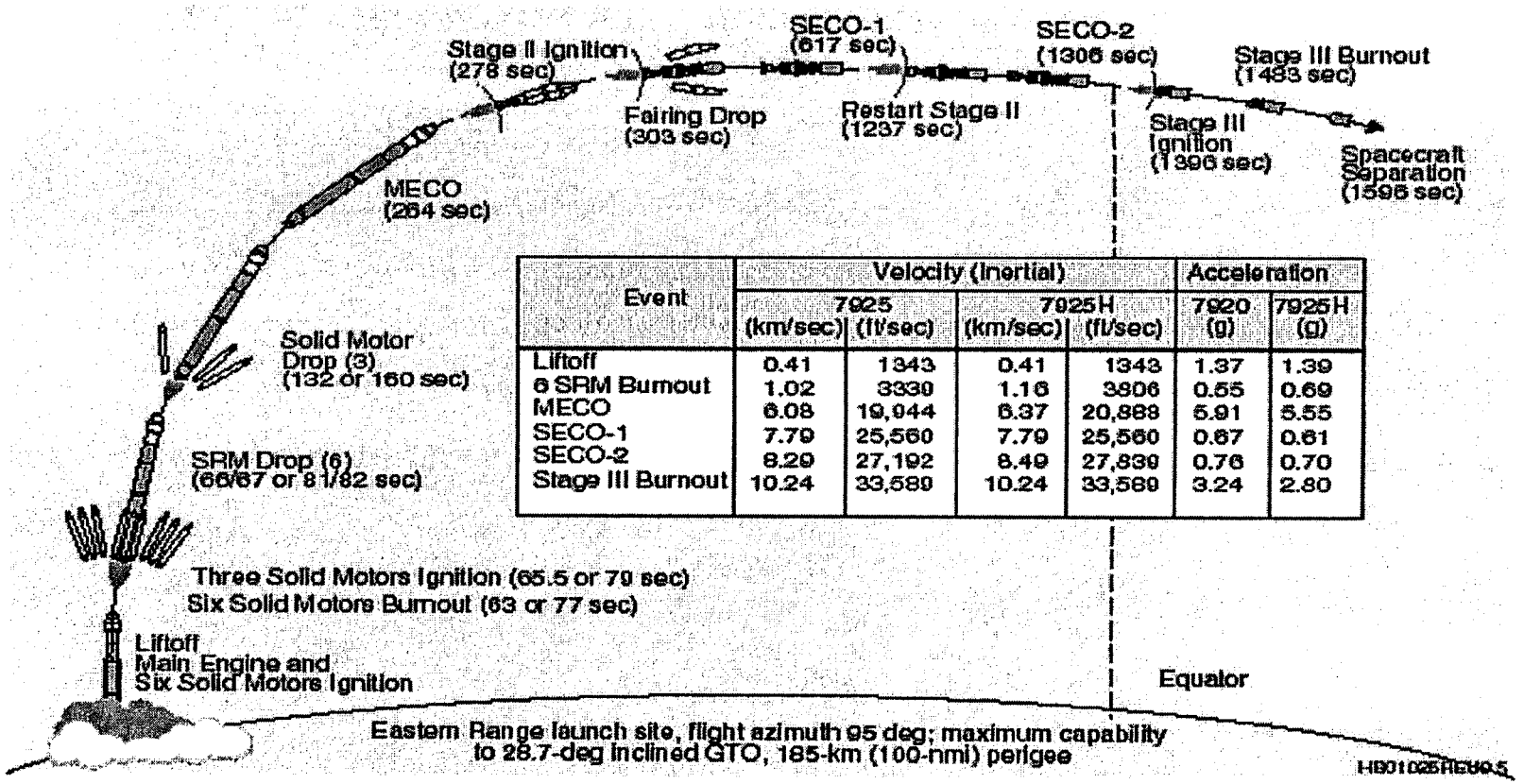
RECOMMEND SOMEONE ADDRESS THIS ELSEWHERE

VIEWGRAPH TO BE REMOVED IN FINAL VERSION

APPENDIX

(1) TYPICAL LAUNCH VEHICLE SEQUENCING & PERFORMANCE
(2) ECLSS

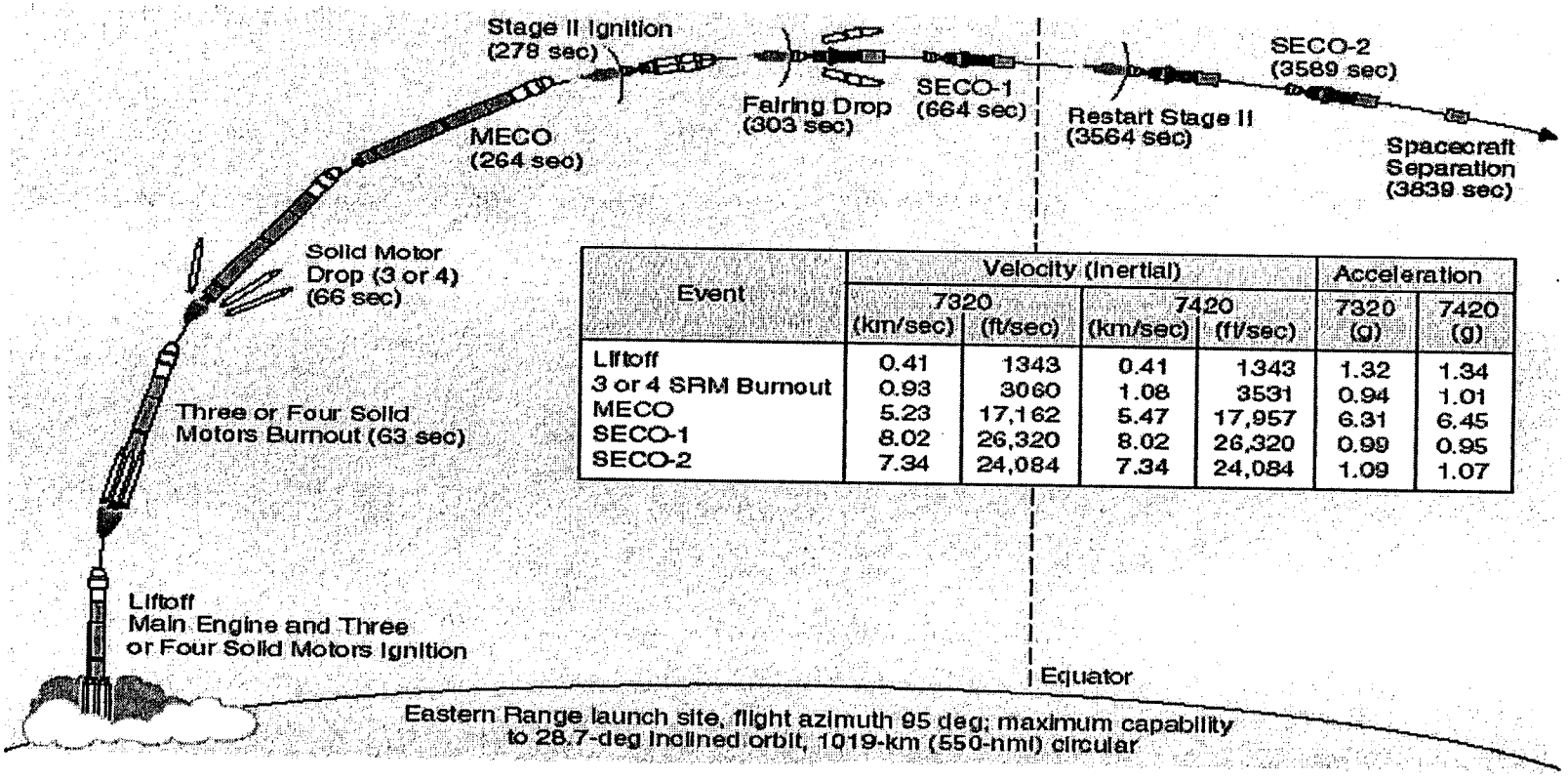
CONCEPT ONLY
NOT SPECIFIC TO OBPR



Event	Velocity (Inertial)				Acceleration	
	7925 (km/sec)	7925 (ft/sec)	7925H (km/sec)	7925H (ft/sec)	7920 (g)	7925H (g)
Liftoff	0.41	1343	0.41	1343	1.37	1.39
6 SRM Burnout	1.02	3339	1.16	3806	0.55	0.69
MECO	6.08	19,944	6.37	20,888	5.91	5.55
SECO-1	7.79	25,560	7.79	25,560	0.67	0.61
SECO-2	8.29	27,192	8.49	27,839	0.76	0.70
Stage III Burnout	10.24	33,589	10.24	33,589	3.24	2.80

Figure 2-5. Typical Delta II 7925/7925H Mission Profile—GTO Mission (ER Launch Site)

CONCEPT ONLY
NOT SPECIFIC TO OBPR



Event	Velocity (Inertial)				Acceleration	
	7320 (km/sec)	7320 (ft/sec)	7420 (km/sec)	7420 (ft/sec)	7320 (g)	7420 (g)
Liftoff	0.41	1343	0.41	1343	1.32	1.34
3 or 4 SRM Burnout	0.93	3060	1.08	3531	0.94	1.01
MECO	5.23	17,162	5.47	17,957	6.31	6.45
SECO-1	8.02	26,320	8.02	26,320	0.99	0.95
SECO-2	7.34	24,084	7.34	24,084	1.09	1.07

Figure 2-3. Typical Delta II 7320/7420 Mission Profile—Circular Orbit Mission (ER Launch Site)

CONCEPT ONLY
NOT SPECIFIC TO OBPR

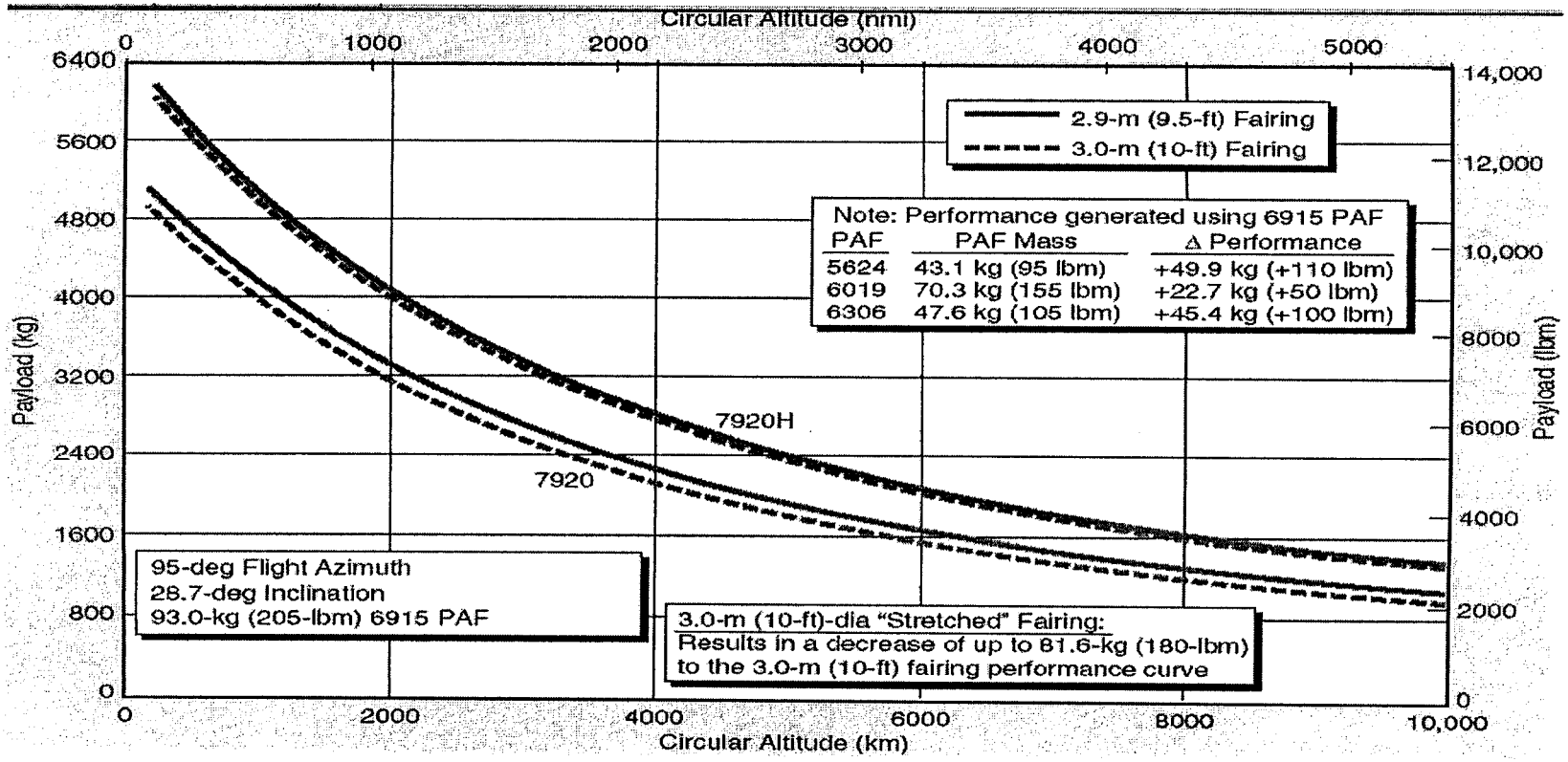
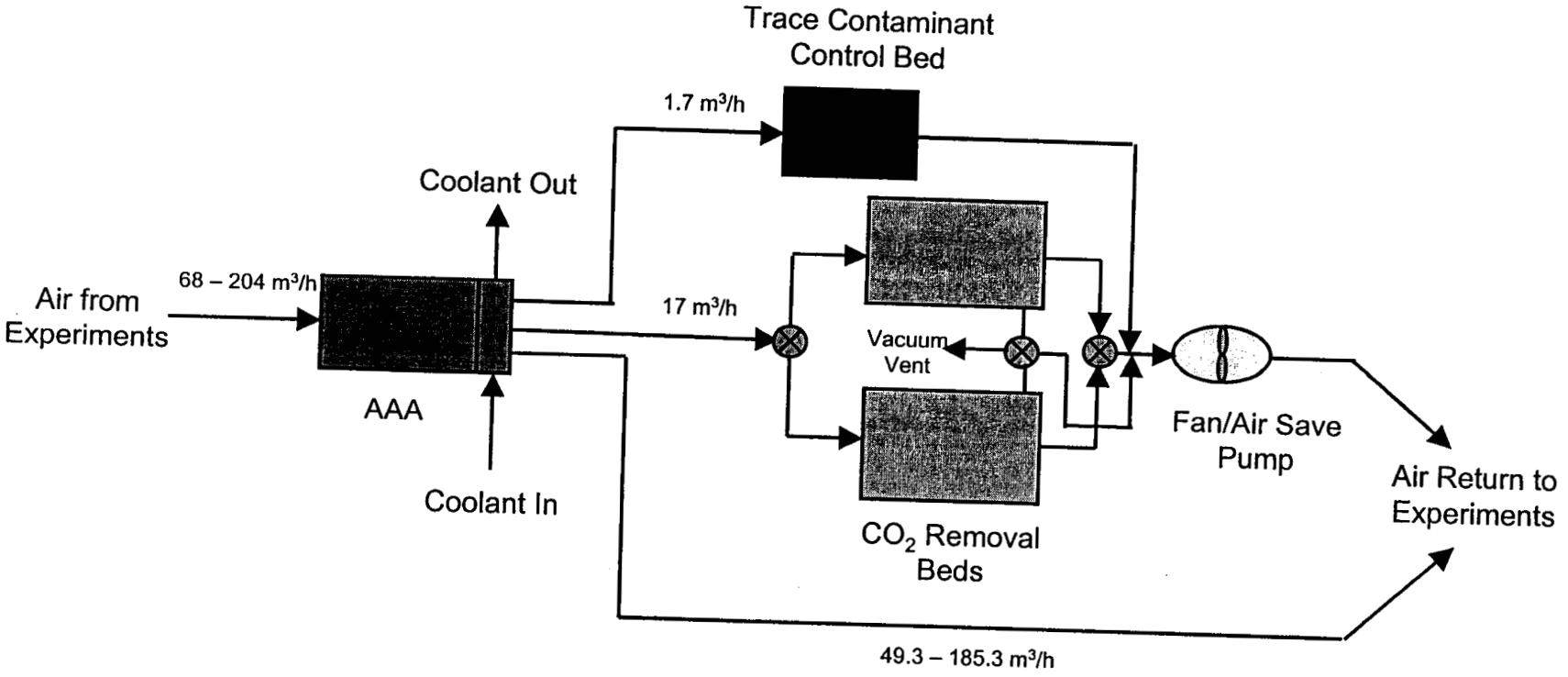


Figure 2-22. Delta II 7920/7920H Vehicle, Two-Stage Circular Orbit Altitude Capability—Eastern Launch Site

FFH RV ECLSS FLOW DIAGRAM



BACKUP

Overview of OBPR Free Flyer Advanced System Concept Study

Ron Leung
NASA/GSFC Code 594

Free Flyer Research Workshop
December 2-3, 2003

Technical Consultation
Al Lieberman
NASA/GSFC Code 594

FFH* Reference Payload Requirements (* = Return from 12 Re + Centrifuge)

Payload	Mass (kg)	Data	Volume	Power (W)	Operation (days)	G-Level
FB03 Mice Radiation	300	Low rate data, 1 kbps (video), 3.6 Mbps for 80 min/day	10 MDLE ($0.54m^3$)	400	90	10^{-3}
PS02 Tissue Model Radiation	140	<1 Mb/day + video of 3.6 Mbps for 30 min every 3rd day	2 MDLE ($0.11\ m^3$)	325	90	10^{-3}
Centrifuge	included in above	TBD		200	90	
TOTAL	**440**		**0.65 m^3**	**925**	**60**	**10^{-3}**

- Mission design assumes a near zero momentum centrifuge

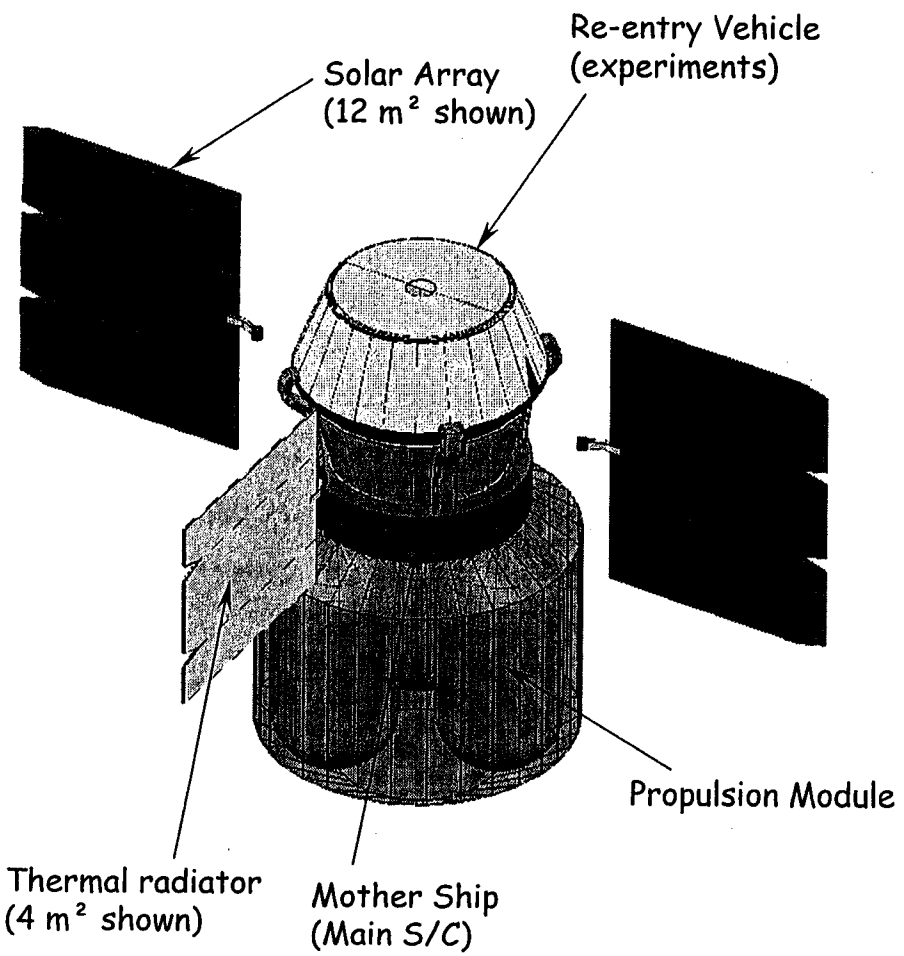
FFH* Driving Mission Requirements

- Provide a returnable on-orbit laboratory on which to fly representative experiment payloads to a microgravity and an interplanetary radiation environment
- Capable of maintaining a low gravity environment (10^{-3}) once payload is delivered to orbit.
- Provide payload re-entry capability to CONUS, reliability of hitting target landing area of 99.95%.
- Provide late access on launch pad (L – a few days to L – a few hours) to load biological samples and materials.
- Maintain the primary launch and re-entry load vector in the same direction
- Maintain G-load throughout mission less than 10 g.
- Maintain payload environment for ~6 hours after beginning of re-entry (based on OBPR-RV study).
- Assess feasibility of placing a 1 g centrifuge on board consisting of half the payload mass.

FFH* Requirements
Mission Parameters

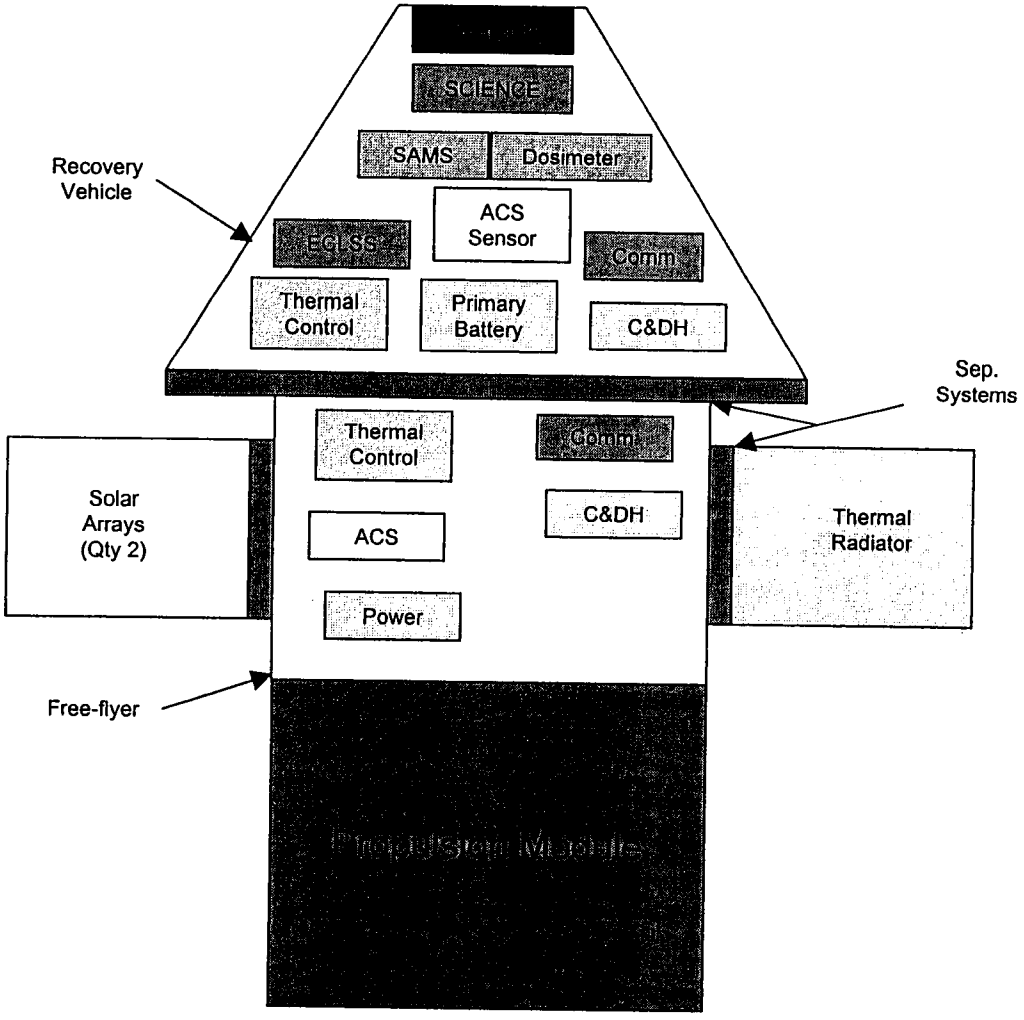
- Orbit requirements:
  - Inclination requirement driven by landing range location
  - Provide payload with exposure to Galactic Cosmic Rays (GCR's) as would be experienced in interplanetary space
- Spacecraft (SC) Driving Requirements
  - Redundancy required to reliably hit the target landing area
  - Design must maintain micro-g environment
- Launch Vehicle
  - **Delta IV Heavy** selected to provide maximum mass to orbit
  - Provide late access to payloads in vehicle processing facility and on launch pad
- Landing Site
  - Continental United Stated (CONUS) desired

FFH* Spacecraft Configuration



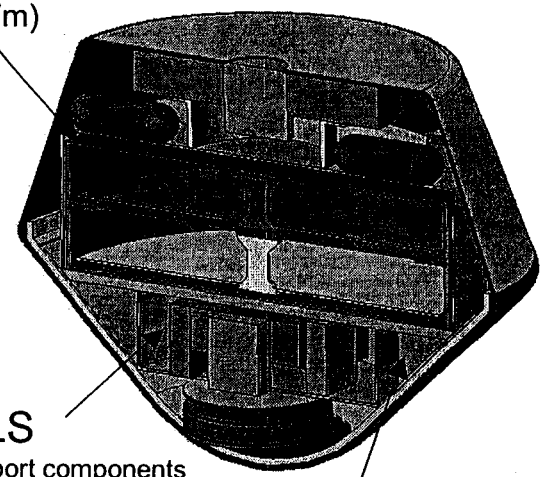
- 3-axis Stabilized, zero momentum
- Extremely large propulsion module with dual mode system providing propulsion and attitude control (over 6000 kg fuel)
- X-band comm. system payload data downlink
- Large thermal radiator
- 60 Gbits Data Storage
- 120 V power system

FFH* BLOCK DIAGRAM CONCEPT



FFH* Dual Counter-rotating Centrifuge Options

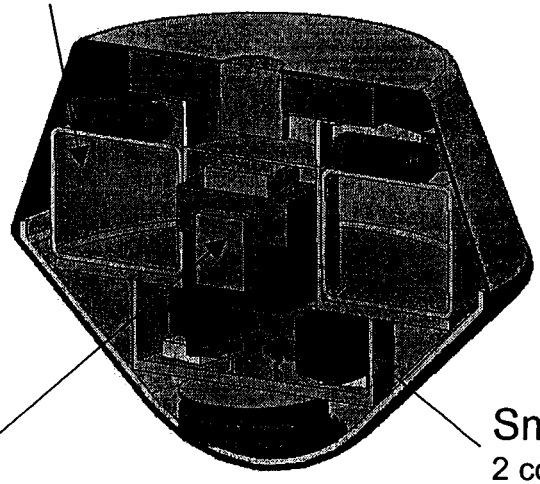
Large Centrifuge
2 counter rotating volumes
1 upper, 1 lower
Total volume 1.60m³
(envelope Ø1.9m x .57m)



ECCLS
Life Support components

Lower Payload Compartment
Total volume 0.22m³
- Volume is between ECCLS housing and the heat shield.
- This volume is non-pressurized.

Upper Payload Compartment
Total volume 1.40m³
(envelope: Ø2.0m x Ø0.70m x 0.6m)



ECCLS
Life Support components

Small Centrifuge
2 counter rotating volumes
1 inner, 1 outer
Total volume 0.22m³
(envelope Ø1.1m x .25m)

FFH* Heavy Summary

- 2 reference payloads (Biological payloads)
  - –total mass 440 kg, volume 0.65 m3
- Payloads are returned to the Earth
- 12 R_E x 48.5 degrees circular orbit – 10-3 micro g on orbit
- Mission Life- 60 days
- Late access to payload on launchpad (biological samples & materials)
- Attitude Control System-Inertial Pointing s/c
- RV Mechanical-modular or toroidal payload concept with centifuge, aluminum honeycomb aeroshell,1.60 m3 total payload volume
- Data- Average data rate 283 kbps, telemetry is x & s band at 10 Mbps & 20 kbps, cmd is s band 2 kbps, 58 hours of data storage 60 Gbits
- Thermal- common cold plate, payloads maintained at 20 deg c, TPS for re-entry aeroshell
- ECLSS- Provides atmospheric constituents, revitalization, monitoring, total pressure control, sensible heat control

Free Flyer (FF)
Total Payload Reference Concept Capabilities

ITEM	FF Medium (FFM)	FF Heavy (FFH)	FF Heavy* (FFH*)	Secondary Payloads of Opportunity
Operational (days)	30 design, 60 goal	30 design, 60 goal	60 design, 90 goal	TBD (ex.hrs to days)
microG (g)	10-e5	10-e5	10-e5	TBD
Orbit	circ 70000 km (12Re) 28.5 deg incl	circ 550 km 40.5 deg incl	Circ 70000 km (12Re) 48.5 deg incl	depends on primary payload
Mass (kg)	170 (1)	920 (1)	440 (2)	0 - 50
Volume (m3)	1.55 (1)	2.5 (1)	1.60 (2)	TBD(ex.0.09-0.009)
Power (kw)	0.25	2	0.93	TBD(ex.0.002-0.060)
Thermal (deg c)	25	20	20	TBD[ex. (-23)-(-12)]
Data (kbps)	58	313	283	TBD (ex. 4-40)

(1)Science payload mass & volume includes payload structure

(2) Science payload mass & volume includes payload structure +centrifuge

Free Flyer Study Derived Constraints FFM, FFH, FFH*

- Dollars
  - Attempt to keep total program costs constrained (e.g. Launch Vehicle)
- Mass Margin (over Delta Launch Vehicle capability)
  - FF Medium (non return,12 Re) 25%
  - FFH (baseline, return, 550 km) 34%
  - FFH* Heavy (return,12 Re,Centrifuge quick look study) 7%
    - Note:a. Margin should be 25% to 35% minimum in formulation
      b. Centrifuge mass is part of payload mass
      c. Centrifuge concept/implementation not studied in any detail
- Volume
  - FFM adequate volume for reference payload
  - FFH adequate volume for reference payload
  - FFH* Heavy with Centrifuge cramped (feasibility of centrifuge needs further detailed study)
- Other
  - FFH & FFH*
    - Landing Site, S/C integration, power, propulsion, thermal