International Conference on Environmental Systems

AIAA The World's Forum for Aerospace Leadership

Low Cost Space Demonstration for a Single-Person Spacecraft

Brand Griffin

Gray Research/NASA, MSFC Engineering, Science, and Technical Services Contract

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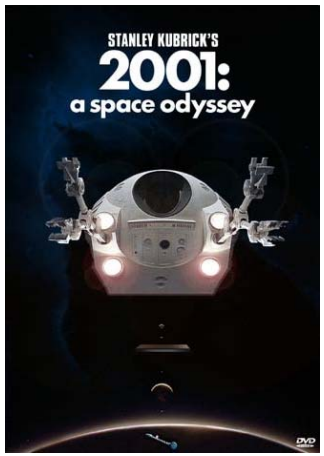
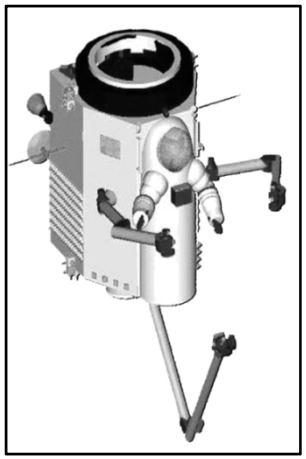
NASA, MSFC

41st ICES, 17–21 July 2011, Portland, Oregon

JACOBS

GRAY RESEARCH, INC. a MacAulay-Brown Company

What is a Single-Person Spacecraft?

1954	1968	1985	2003	2010
 				
Bottle Suit	Pod	MAWS	SCOUT	FlexCraft (*née* MAWS)

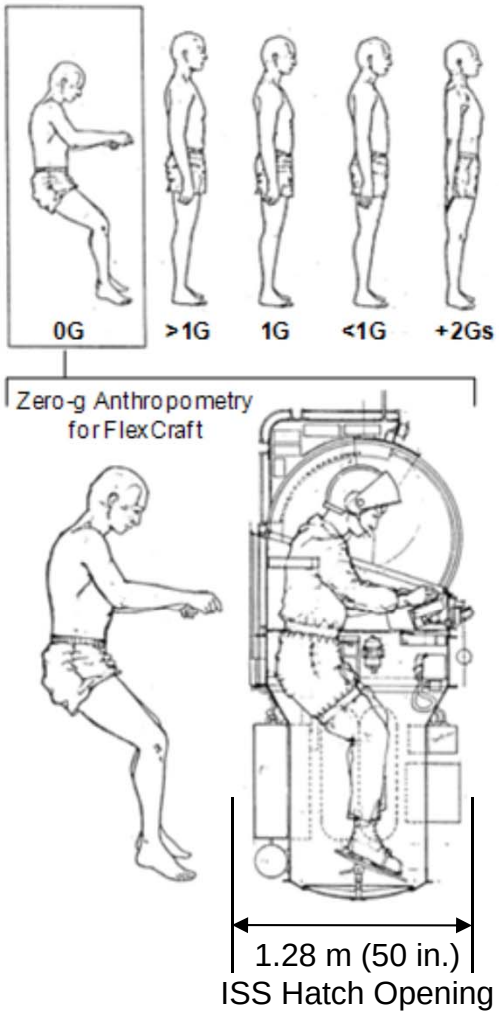
Baseline: FlexCraft (Multiple Venues with Human and Robotic Operations)

Key attributes of baseline concept:
Operates with a host spacecraft
Cabin atmosphere is the same as the host
Includes a propulsion system
Uses manipulators

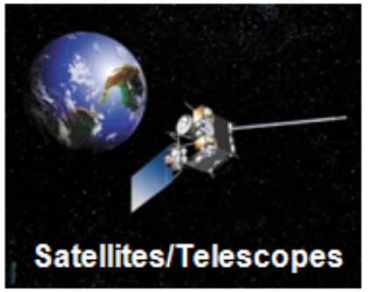
Idea is not new and there are many configurations

FlexCraft Configuration

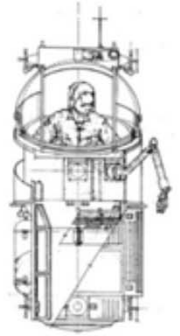
Multiple Venues with Human and Robotic Operations



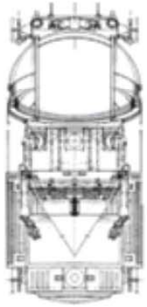
Venues



Operations



Human or Robotic



Mission and Launch Vehicle

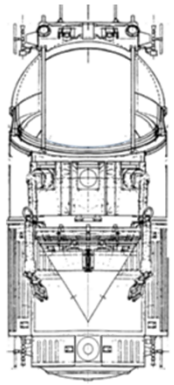
Bare bones Demonstrator

REMOVED/SIMPLIFIED

1. Simplified Canopy Closure
2. Demonstrator Manipulators
3. No Displays and Controls
4. No ECLSS
5. Heaters, but no active thermal control
6. No experiment/sample bin
7. No internal outfitting
8. No Hatch
9. No docking mechanism

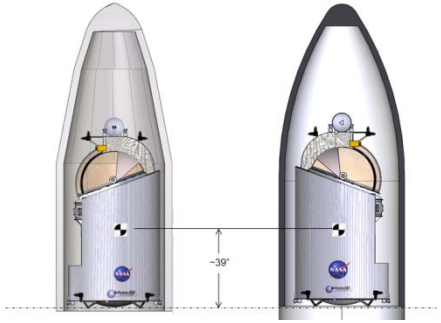
ADDED

1. Test instrumentation
2. Test Communications



Two Launch Vehicle Options

Within mass and cg limits



Minotaur 1 *Falcon 1e*

Significant Margin to 350 km

Vehicle	Falcon 1e	Minotaur I w/ 61" fairing
Data source	Guide	Guide
Launch Site	RTS	CCAFS*
Inclination	9.1	28.5
Notes:	1,3,4	1,2
Circular Orbit Alt (km)	Payload to orbit (kg)	
200	1005	**577**
250	970	**565**
300	**975**	**553**
350	**955**	**541**
400	**940**	**527**
Max longitudinal CG offset for 500kg payload (m)	1[8]	1.0 [7]

Safe Re-entry

Falcon 1e 30 days

Minotaur 1 20 days

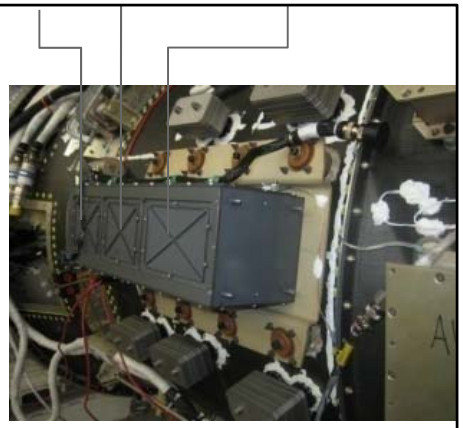
DAS estimate for frontal area		
	Area (m^2)	Area/Mass
Fixed	3.04	0.00869
Grav grad	3.03	0.00866
Tumbling	2.83	0.00809
Addnl area protrusions (m^2)		0.1
Area/Mass for analysis		0.00897

Short Mission

(Reduced Cost)

Upper Stage Target

ISS, NEO and Satellite tasks



Configuration

Pressure Vessel

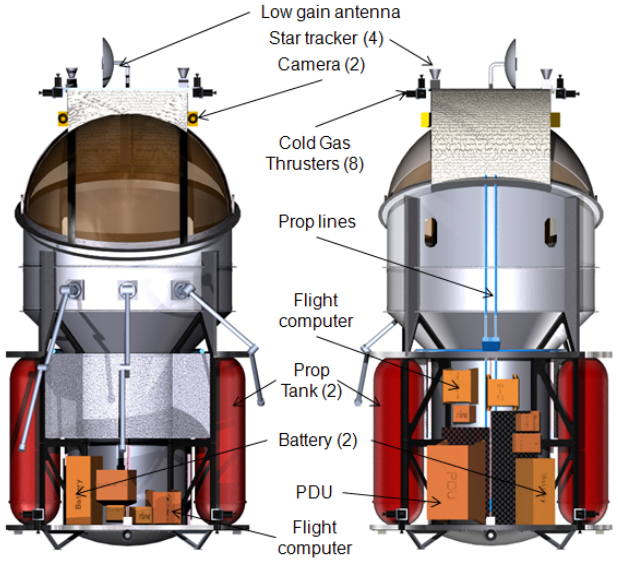
Secondary Structure

Subsystem Packaging

MMOD Shield

Mature Technologies

System	Demonstrator TRL								
	1	2	3	4	5	6	7	8	9
Structures									
Electrical									
Thermal									
Propulsion									
GN&C									
Comm									
Robotics									

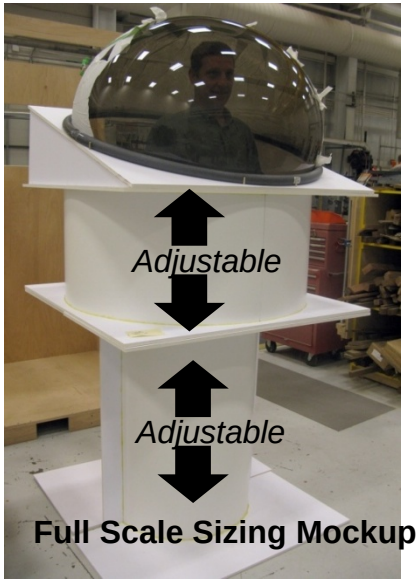


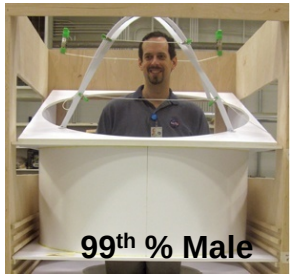
AIAA Standards for MGA

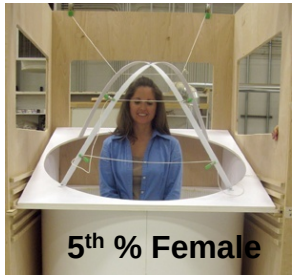
FlexCraft		Predicted Mass (kg) inc MGA
1.0	Structures	123.86
2.0	Propulsion	52.20
3.0	Power	46.78
4.0	Avionics	53.13
5.0	Thermal	23.38
6.0	Separation Ring	8.87
Dry Mass		**309.26**
7.0	Non-Prop Fluids	1.22
8.0	Cargo/Payload	65.49
Inert Mass		**59.22**
Total Less Propellant		**368.48**
9.0	Propellant	14.25
Total Gross Mass		**382.73**

Mockups

Sizing Mockup







Pressure Vessel Enclosure

MMU and FlexCraft

Systems are Available to Support Launch in 3 yrs.

"Design to Availability"

Subsystem	Options	Source	Availability?	
Attitude Control System	Sun Sensor (and electronics)	Sinclair Intr, SS-411 MSS	1 Available now (2 weeks), otherwise 4-6 months lead time.	★
	Star Tracker WFOV	AeroAstro Mini tracker	Waiting for a response	★
	Star Tracker	Sinclair Intr	2011	★
	IMU Assy	Northrop LN200	Waiting for a response	★
Thermal System	Same as MMU – Some located in SRC	NASA/Space Rocket Center	Now.	
	Heaters - Heater tape and wire, Kapton covered	Clayborn Labs	Couple of weeks	★
	Thermostats	TBD	Assumed a couple of weeks	
	Temperature Sensors - RTDs layered in adhesive backed Kapton sheet	Minco/Rockwell	Waiting for a response	
Propulsion System - Thrusters	Same Thrusters as MMU - Triad Thrusters	Vacco Space Products	10-12 months	★
	Cold Gas Thruster (Larger Thrust)	MOOG	~11 months	
	Cold Gas Thruster (Smaller Thrust)	MOOG	~11 months	
	Cold Gas Thruster Triad	MOOG	~11 months	
Propulsion System - Plumbing	Made in House	NASA	Need Manufacturer Estimation.	
Propsulsion System - Tanks	Shorter Tanks (OAL: 64.3 - 88.9cm)	Structural Composite Industries (A company of Worthinton Cyclinders)	2-12 weeks. Depending if model selected is popular.	★
	Longer Tanks (OAL: ~187.2cm)	Structural Composite Industries (A company of Worthinton Cyclinders)	2-12 weeks. Depending if model selected is popular.	
	Same as MMU - (would have to be created, none currently matches the exact spec.)	Structural Composite Industries (A company of Worthinton Cyclinders)	2-12 weeks. Depending if model selected is popular.	
Robotic Arms (7 DoF)	Mars 7-DOF Manipulator (New Development)	TRACLabs, Inc. http://traclabs.com/mars7dof.html	Mid 2011 - may be longer due to needed modifications	★
Communication System from Ground	TDRSS data link from:	GRGT (Guam), GSFC (Goddard MD), WSGT (White Sands)	Now - May need modifications.	★
	UHF link with ISS	NASA	Now - May need modifications.	
Structure	Materials the same as MMU, Aluminum (2219). Needs to be custom manufactured.	Manufacturers of the materials used for the structure include Martin Marietta Corp., Hugson, Carpenter, Honeywell and Bray Oil Co.	Need to be manufactured. Estimate from manufacturer.	★
	One-Pilot Submarine	Argo-A-Security or Trisektor	TBD	

★ Chosen System

Longest Lead Times:

Flight Computer (up to 16 months)

Thruster Triads (12 months)

Primary Battery (12 months)

GPS System (12 months)

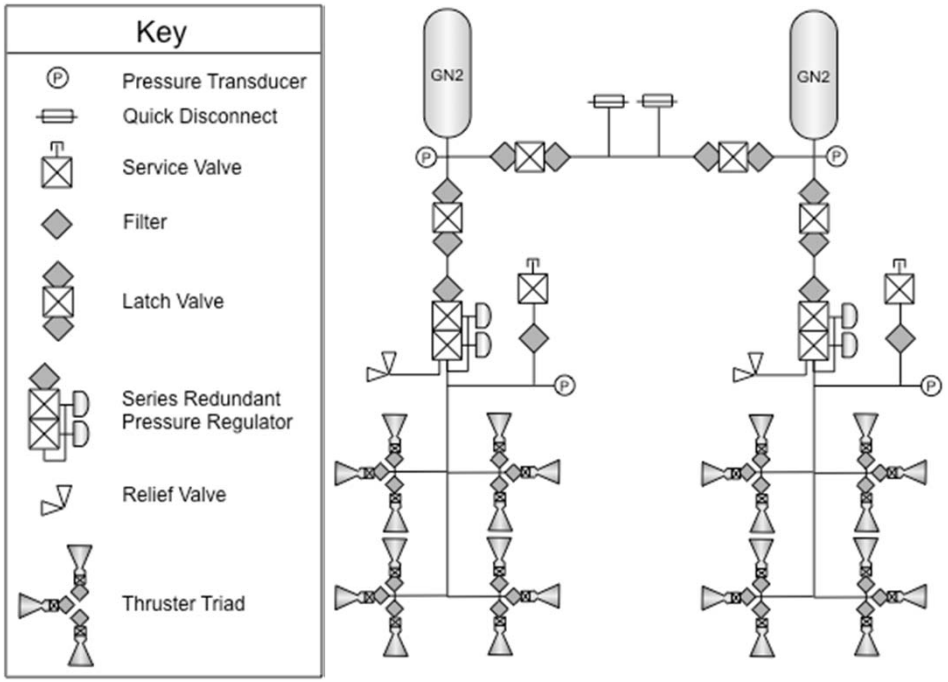
Propulsion System (Repackaged MMU)

Overview

- Cold gas (nitrogen) propulsion system
- Eight thruster triads
  - Provides rotational and translational control
  - Redundant A and B sets
- Total maneuver propellant = 14.2 kg (31.4 lbm)
  - Assumes tank drain from 3400-to-250 psi
  - Total loaded nitrogen = 15.5 kg (34.1 lbm)

Key Features

- VACCO 2 lbf thrusters (same as MMU)
- COTS tank: 1900 in^3, 3400 psi
  - Structural Composites Industries
    (Worthington Cylinders Company)
- Redundant A and B systems
- High TRL



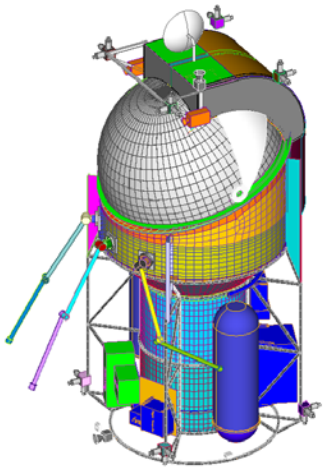
Component	Qty	Unit Mass (kg)	Basic Mass (kg)	AIAA Category & Code	MGA	Predicted Mass (kg)	Comments/Information
Thruster Triad	8	1.41	11.28	A5	2%	11.51	VACCO 2 lbf cold gas thruster triad
Pressure Vessel	2	15.65	31.30	A5	2%	31.93	Worthington Cylinders Tank
Regulator/Relief Valve	2	0.36	0.72	C4	4%	0.75	MMU component
Crossfeed Valve	2	0.45	0.90	E2	12%	1.01	MMU component
Isolation Valve	2	1.20	2.40	C4	4%	2.50	MMU component
Quick Disconnect	2	0.41	0.82	C4	4%	0.85	MMU component
Filter	2	0.25	0.50	E1	18%	0.59	Estimate
Pressure Transducer	2	0.20	0.40	C4	4%	0.42	Typical Value
Pressure Gauge	2	0.08	0.16	C3	8%	0.17	MMU Component
Service Valve	2	0.21	0.42	C4	4%	0.44	MOOG Low Pressure Valve
Lines & Fittings	1	1.74	1.74	E1	18%	2.05	Estimate
			50.64 kg	***Total Dry Mass:***	***3.1%***	***52.20 kg***	

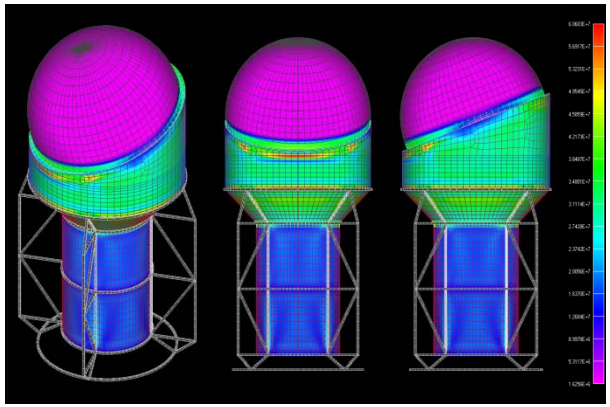
Structures

Minotaur Launch Loads

TABLE 4-1. PAYLOAD CG PARAMETRIC DESIGN LIMIT LOADS	Payload Mass 1600 lbm (725.7 kg)	
	Axial (G) max/min	Lateral (G)
Liftoff	3.83/0.27	0.62
Pre-Transonic Resonant Burn	5.05/0.83	0.02
Transonic	5.13/1.52	1.23
Supersonic	3.41/3.40	1.96
Stage 2 Ignition	3.93/-0.35	4.05
Stage 3 Ignition	6.79/0.00	0.78
Stage 3 Burnout	See Figure 4-3	TBS
Stage 4 Burnout	See Figure 4-3	TBS

Pressure Vessel Stress Plot





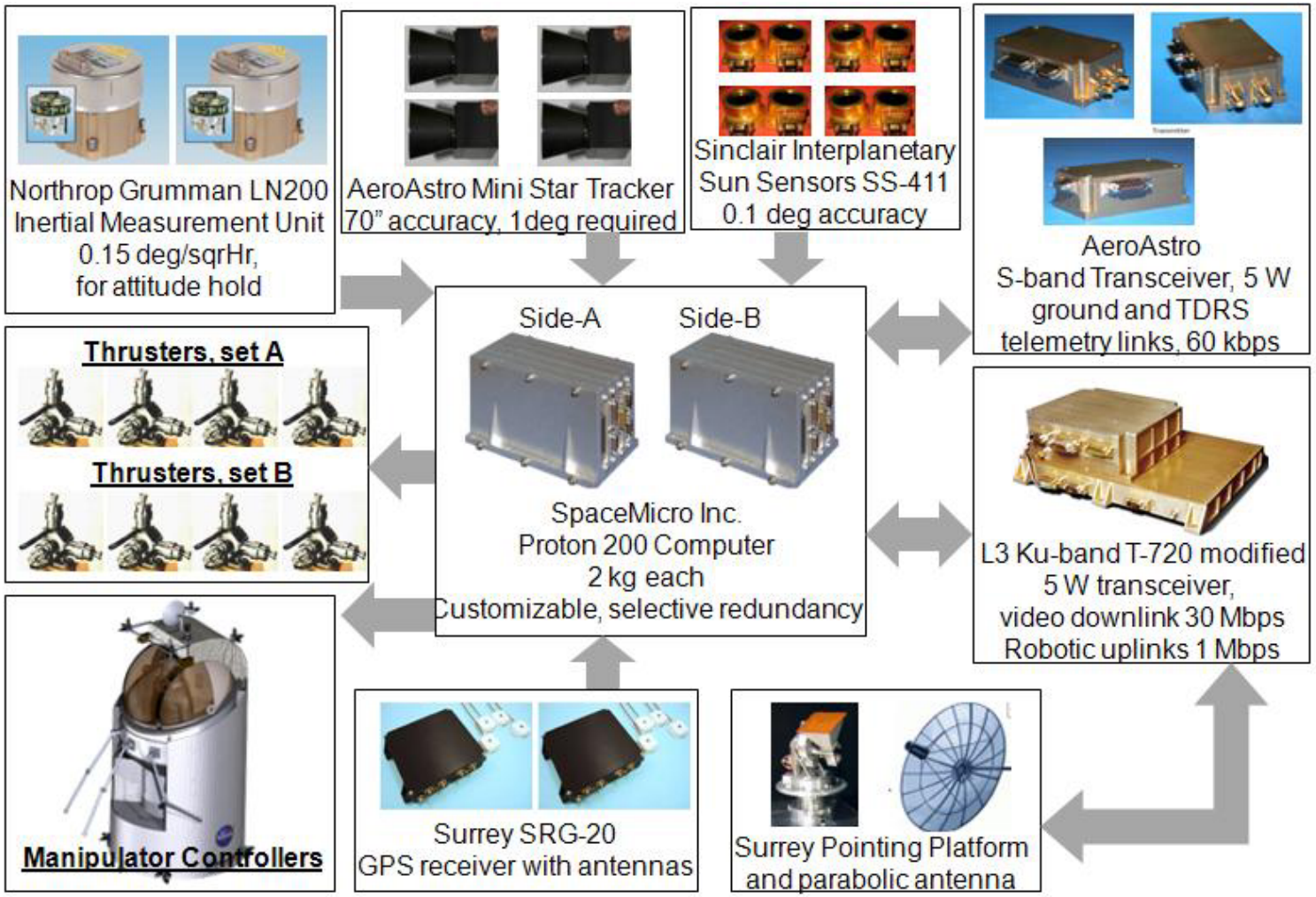
Launch Vehicle & Loads:
- Minotaur loads from Payload Planner's Guide
- Integrate with standard Payload Attach Fairing
- Minimum Natural Frequency > 25Hz

Factors of Safety
- Yield: 1.25
- Ultimate: 1.4
- Pressure Vessel: 2.0

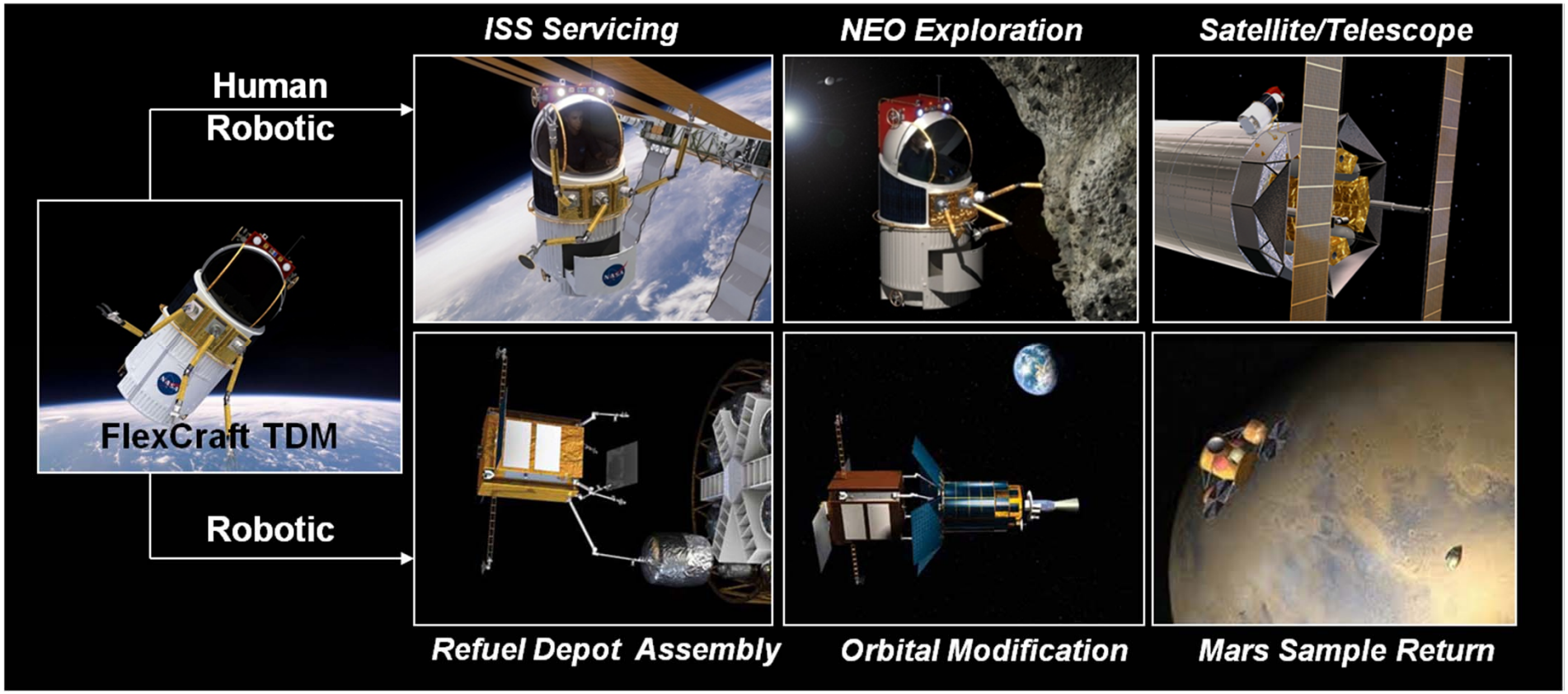
Materials:
- AL 2219 – T87: Pressure Vessel Structure
- AL 7075 – T651: Ringframes & Spars
- Lexan 1500 Polycarbonate: Dome

Component	Qty	Unit Mass (kg)	Basic Mass (kg)	AIAA Category & Code	MGA (%)	Predicted Mass (kg)	Comments/Information
Dome	1	29.48	29.48	E1	18.00%	34.79	Lexan 1500 Polycarbonate
Dome Collar	1	3.23	3.23	E1	18.00%	3.81	AL7075 – T651
Mid Cylinder	1	11.46	11.46	E1	18.00%	13.52	AL2219 – T87
Frustum	1	4.68	4.68	E1	18.00%	5.52	AL2219 – T87
Lower Cylinder	1	7.91	7.91	E1	18.00%	9.33	AL2219 – T87
Bottom Plate	1	8.21	8.21	E1	18.00%	9.69	AL2219 – T87
Lower Spar	4	5.00	20.00	E1	18.00%	23.60	AL7075 – T651
Secondary Structure	1	7.00	7.00	E1	18.00%	8.26	TBD
Joints & Fittings	1	13.00	13.00	E1	18.00%	15.34	TBD
Total Dry Mass:			***104.97 kg***		***18%***	***123.86 kg***	

Avionics


Northrop Grumman LN200
Inertial Measurement Unit
0.15 deg/sqrHr,
for attitude hold
AeroAstro Mini Star Tracker
70" accuracy, 1deg required
Sinclair Interplanetary
Sun Sensors SS-411
0.1 deg accuracy
AeroAstro
S-band Transceiver, 5 W
ground and TDRS
telemetry links, 60 kbps
Thrusters, set A
Thrusters, set B
Side-A
Side-B
SpaceMicro Inc.
Proton 200 Computer
2 kg each
Customizable, selective redundancy
L3 Ku-band T-720 modified
5 W transceiver,
video downlink 30 Mbps
Robotic uplinks 1 Mbps
Manipulator Controllers
Surrey SRG-20
GPS receiver with antennas
Surrey Pointing Platform
and parabolic antenna

After the Demonstration



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