# Low Cost Space Demonstration for a Single-Person Spacecraft

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**This paper introduces a concept for a single-person spacecraft and presents plans for flying a low-cost, robotic demonstration mission. Called FlexCraft, the vehicle integrates propulsion and robotics into a small spacecraft that enables rapid, shirt-sleeve access to space. It can be flown by astronauts or tele-operated and is equipped with interchangeable manipulators used for maintaining the International Space Station (ISS), exploring asteroids, and servicing telescopes or satellites. Most FlexCraft systems are verified using ground facilities; however, a test in the weightless environment is needed to assess propulsion and manipulator performance. For this, a simplified, unmanned, version of FlexCraft is flown on a low-cost launch vehicle to a 350 km circular orbit. After separation from the upper stage, the vehicle returns to a target box mounted on the stage testing the propulsion and control capability. The box is equipped with manipulator test items that are representative of tasks performed on ISS, asteroid missions, or for satellites servicing. Nominal and off-nominal operations are conducted over 3 days then the vehicle re-enters the atmosphere without becoming a debris hazard. From concept to management to operations, the FlexCraft demonstration is designed to be low-cost project that is launched within three years. This is possible using a simplified test configuration that eliminates nine systems unique to the operational version and by "designing-to-availability." For example, the propulsion system is the same as the Manned Maneuvering Unit because it capable, simple, human-rated and all components or equivalent parts are available. A description of the launch vehicle options, mission operations, configuration, and demonstrator subsystems is presented. In addition, discussions on the use of mockups, cost reduction, management approach and the innovative application of Army helicopter simulation facilities are included..**

## I. Introduction

VISIONS of a single-person spacecraft are not new (Fig.1). In 1954, Werner vonBraun conceived of a bottle suit and science fiction is replete with designs most notably, the pod featured in the 1969 movie *2001 A Space Odyssey*. In addition, there have been numerous engineering studies however after all these years, not one has flown. FlexCraft is designed to fly, first as an expendable, robotic demonstrator then as a human-rated spacecraft operating at the International Space Station, servicing satellites, and exploring asteroids. Because all other FlexCraft systems can be verified on the ground, the demonstrator focuses on testing the propulsion and manipulator systems in the relevant weightless environment. For this, the FlexCraft demonstrator is a simplified, unmanned, version specifically configured for propulsion and manipulator testing.

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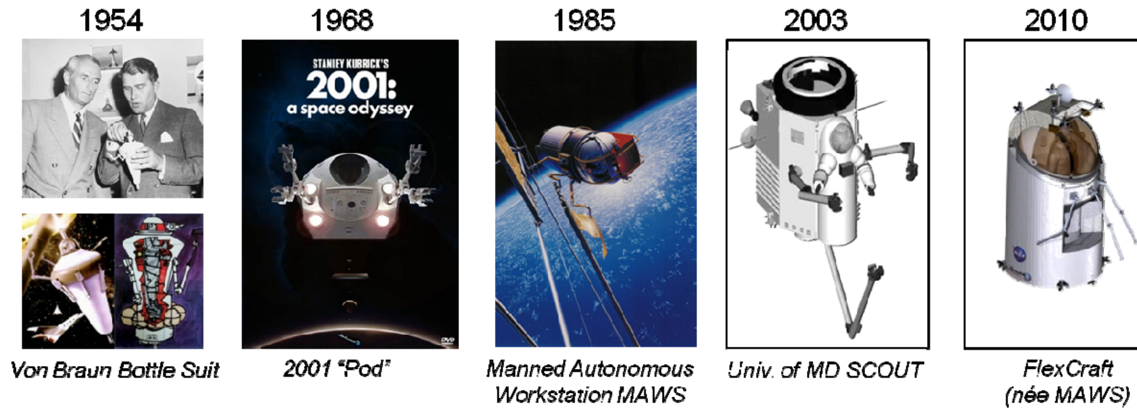



**Figure 1. There are many concepts for a single-person spacecraft but none have flown in space.**

## II. Demonstration Mission

The demonstration mission was conceived to be low-cost and fly within three years. These constraints became an ally rather than the adversary, helping to shape a focused, effective, and achievable mission plan. Early analysis confirmed the human-rated Manned Maneuvering Unit (MMU) propulsion system as the safest and most effective solution. Equally important, the parts are still available. With respect to the non mission-specific hardware and software, the approach was "Design to Availability." This meant if the item was not available for ground test and launch integration, then change the design until it was. This was not as radical as it sounds, because the FlexCraft demonstrator is very simple, less complex than most automobiles, and there are flight-rated alternatives for every system. To further simplify the mission and lower cost, nine systems, such as the life support, were eliminated from the demonstration configuration. To validate propulsion system, it is critical that the demonstrator thruster performance and geometry be the same as the operational vehicle. The Minotaur 1 and Falcon 1e are two "low cost" launch vehicles providing a good fit for the demonstrator volume, mass, and center of gravity (Fig. 3). With a demonstrator mass less than 400 kg, a circular orbit of 350 km was selected. Including insertion error and mass margin, this altitude is high enough to provide adequate test time while low enough to assure a destructive reentry in less than 30 days.

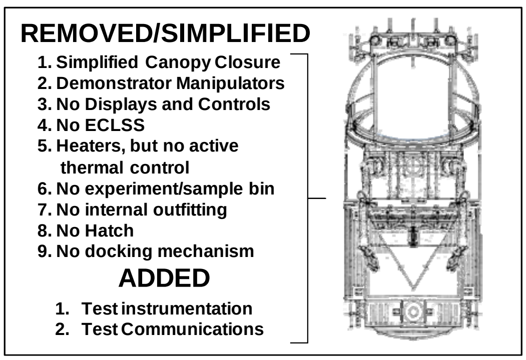



**Figure 2. Nine systems removed**

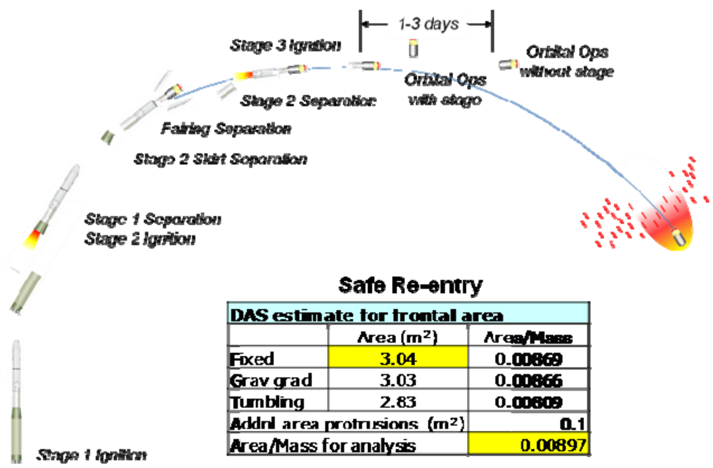
Within mass and cg limits

| | Falcon 1e | Minotaur I w/ 61" fairing |
|---|---|---|
| CG Offset (500 kg) | 1 m | 1 m |
| Circular Orbit Alt (km) | Payload to orbit (kg) | |
| 300 | 975 | 553 |
| 350 | 955 | 541 |
| 400 | 940 | 527 |

Orbit Lifetime

Orbit lifetime estimated using DAS (select cases validated with Satellite Took Kit). Recommended target orbit conservatively accounts for orbit injection errors.

| | Falcon 1e | Minotaur I |
|---|---|---|
| Target Orbit | 325km circular | 350km circular |
| Final Orbit | 320 x 310 km | 331.5 x 257.4 km |
| Lifetime | 30 days | 20 days |
| Payload | 965 kg | 545 kg |




| DAS estimate for frontal area | Area (m²) | Area/Mass |
|---|---|---|
| Fixed | 3.04 | 0.00869 |
| Grav grad | 3.03 | 0.00866 |
| Tumbling | 2.83 | 0.00809 |
| Addnl area protrusions (m²) | | 0.1 |
| Area/Mass for analysis | | 0.00897 |

**Figure 3. Two launch vehicles available for short robotic demonstration mission**

The FlexCraft demonstration mission is not intended to fly to ISS. In fact, for the demonstration flight it is not desirable to operate around ISS because this brings requirements that add to cost and schedule. Operational FlexCraft excursions will vary in time but should not last more than 6 hours. This means a short demonstration flight is acceptable for assessing propulsion and manipulator performance and desirable for reducing cost. Consequently, the mission is planned for 24 hours (approximately 16 orbits and two long shifts for ground controllers) but not to exceed 3 days.

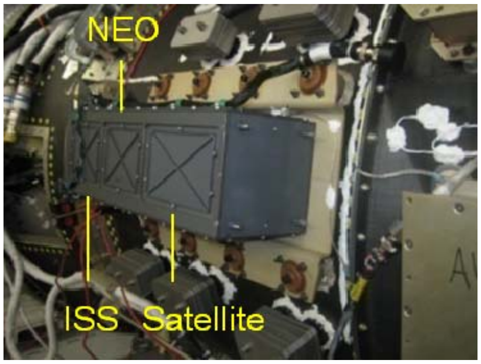


**Figure 4. Upper stage test box**

Once reaching orbit, FlexCraft will separate from the upper stage then return to a target box mounted on the stage (Fig 4). Rather than the traditional pyrotechnique or spring separation, FlexCraft will employ a novel manipulator technique. Vehicle Manipulators are programmed to reach and release launch restraints then the propulsion system performs the separation allowing an assessment of both systems early in the mission. Shortly after separation, the spacecraft will perform an attitude-hold posing for photo-documentation *a la* Bruce McCandless in the MMU (Fig. 5). The box is equipped with manipulator tests that are representative of tasks performed on ISS, asteroid missions, and for satellites servicing. FlexCaft will approach the box and conduct propulsion/manipulator operations for as long as the stage remains stable. Once complete or when the upper stage exceeds FlexCraft control capabilities, it will separate having accomplished the principal test objectives. With remaining propellant and or battery life, bonus testing will assess control of off-nominal conditions.


**Figure 5. McCandless flying the MMU**

The overall technical approach stresses a simple spacecraft design, the use of mature systems, and buying versus making hardware. The fewer the number of systems the simpler the spacecraft and using mature hardware buys down the risk. The FlexCraft demonstrator uses 90 percent off the shelf components including the propulsion system, avionics, batteries, and the power distribution units. The approach for the elements that are built is to use conventional space materials and processes. For example, the pressure vessel is made from the aluminum alloy 2219-T87, the ring frames and spares from 7075-T651, and the canopy from a Lexan 1500 polycarbonate. These materials are commonly used, have predicable properties, and are readily available.

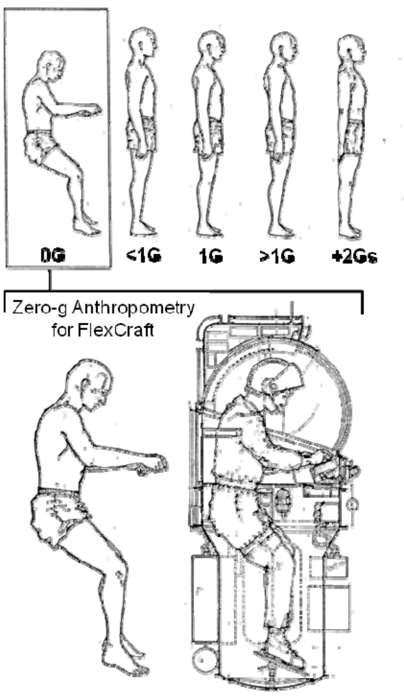


**Figure 6. Specifically designed for weightless body posture**

### A. FlexCraft Configuration.

The overall vehicle configuration integrates an inner pressure vessel for shirtsleeve operations and an outer cylinder for micrometeoroid orbital debris (MMOD) and impact protection. Because astronauts do not sit down in zero gravity, the pressure vessel is shaped around the weightless neutral body posture (Fig. 6). A structurally efficient hemispheric canopy provides a wide field of view for situational awareness and excellent visibility for manipulator work. The canopy is attached to an upper cylinder that accommodates crew arm movements and internal equipment outfitting while a smaller diameter lower cylinder encloses the legs and serves as a tunnel for ingress/egress. The volume between the MMOD shielding and the pressure vessel is used for passive thermal control and packaging the subsystems. Because the demonstrator geometry is the same as the human-rated version, a sizing study was conducted to assess the internal crew dimensions required for one-size-fits-all. For this, an adjustable mockup was used to fit the anthropometric extremes of the astronaut design population (Fig. 7). Test

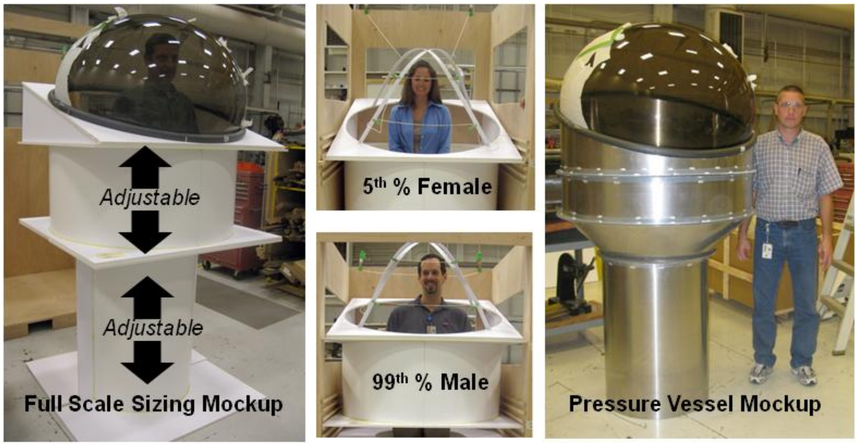


**Figure 7. Mockups assess key dimensions and demonstrator packaging**

subjects assumed the weightless neutral body posture for the 1g internal volume assessments. Furthermore, sizing evaluations took into account the volume and location associated with internal outfitting however, the robotic demonstrator does not include these systems. Once the key dimensional data was collected, a mockup of the pressure vessel was constructed. This will be used to verify the mounting of external subsystems along with the routing of plumbing lines and wire harnesses.

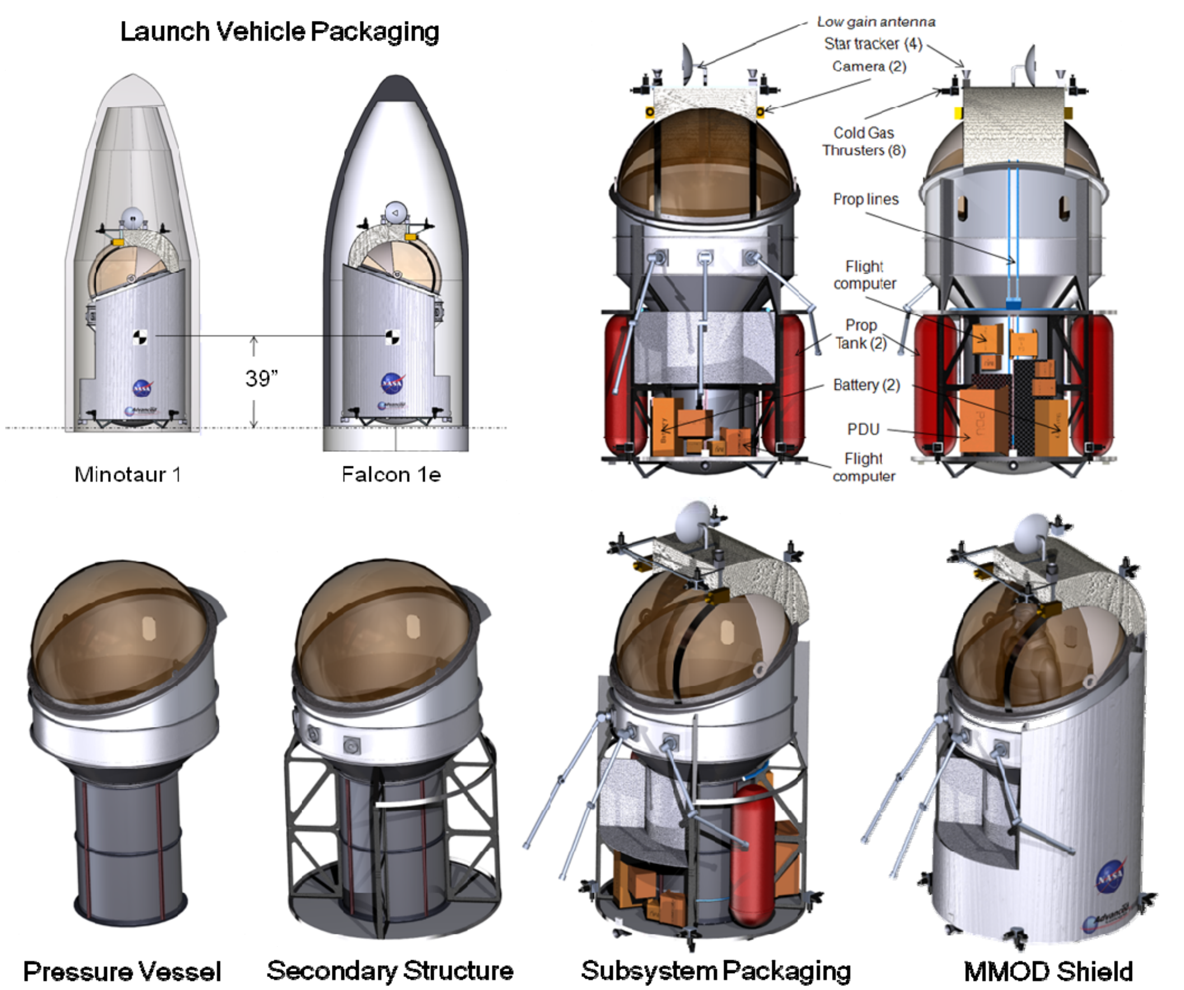


**Figure 8. Flight proven subsystems are packaged for demonstration mission**

Although the demonstrator is configured for propulsion and manipulator testing, it is conceived with the operational version in mind. Most systems are the same as the operational version and because of their heritage, they are human-rated. For example, using the MMU propulsion system inherits the flight experience of six astronauts on three Shuttle missions. In addition, the FlexCraft pressure vessel was sized for the human-rated safety factor, because there is little additional mass and this allows a low cost transition to the operational spacecraft.

**Table 1. Mass estimate includes AIAA standard growth allowance**

| FlexCraft - Mass Summary | | Basic Mass (kg) | MGA (%) | MGA (kg) | Predicted Mass (kg) |
|---|---|---|---|---|---|
| Mass Breakdown | | | | | |
| 1.0 | Structures | 104.97 | 18.00% | 18.89 | 123.86 |
| 2.0 | Propulsion | 50.64 | 3.09% | 1.57 | 52.20 |
| 3.0 | Power | 42.42 | 10.28% | 4.36 | 46.78 |
| 4.0 | Avionics | 45.47 | 16.85% | 7.66 | 53.13 |
| 5.0 | Thermal | 21.00 | 11.33% | 2.38 | 23.38 |
| 6.0 | Separation Ring | 8.70 | 2.00% | 0.17 | 8.87 |
| Dry Mass | | 273.20 | 13.20% | 36.06 | 309.26 |
| 7.0 | Non-Prop Fluids | 1.22 | | | 1.22 |
| 8.0 | Cargo/Payload | 58.00 | 12.91% | 7.49 | 65.49 |
| Inert Mass | | 59.22 | | | 59.22 |
| Total Less Propellant | | 332.42 | | | 368.48 |
| 9.0 | Propellant | 14.25 | | | 14.25 |
| Total Gross Mass | | 346.67 | | | 382.73 |

Using industry-accepted AIAA factors for mass growth allowance (MGA), FlexCraft has a weight (with propellant) of less than 400 kg. Even with an additional 15 percent management reserve, this is within the payload mass and center of gravity requirements for both candidate launch vehicles. Table 1 shows the FlexCraft estimated total mass by subsystem.

## B. Demonstrator Subsystems

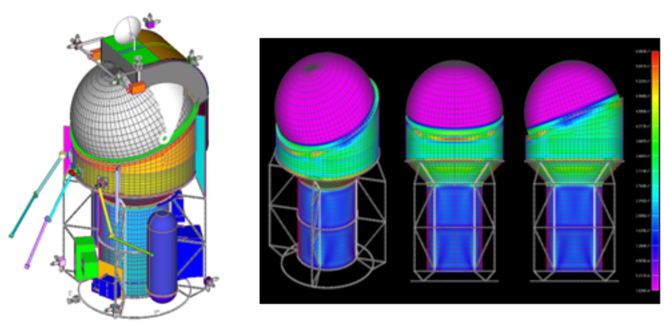
### *1. Structures*

The demonstrator structure is simple, designed for flexible outfitting, and constructed using conventional space materials and processes. The pressure vessel is sized for 1 atmosphere (atm) and launch loads are carried through four spars attached to the pressure vessel. These spars define the equipment bays for subsystem packaging (Figure 9). Coupled with circumferential flanges, this arrangement offers efficient load paths for mounting subsystem components, plumbing, and wiring harnesses. All hardware is packaged in a single layer so that no component has to be removed to access another. Likewise, plumbing and wiring harnesses are mounted on the pressure vessel cone, which provides increased surface area for easy access.

**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**

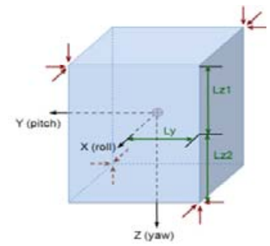
**Materials:**
- **AL 2219 – T87: Pressure Vessel Structure**
- **AL 7075 – T651: Ringframes & Spars**
- **Lexan 1500 Polycarbonate: Dome**

| 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 | |

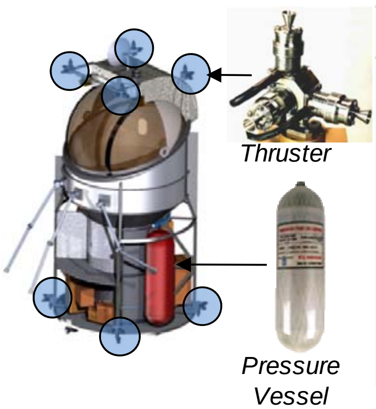
**Figure 9. Demonstrator structural system uses conventional aerospace materials**

*2. Propulsion (TRL 8)*

FlexCraft is designed to take advantage of the millions of dollars invested in developing the MMU human-rated propulsion system. Astronauts flew this cold-gas system on three missions before it was removed from NASA's flight inventory. FlexCraft uses this system because the compressed nitrogen is non-contaminating; it is a simple and reliable solution; and with a cross-strapped, dual-string architecture, it offers fail-op redundancy with very little increase in mass. Like the MMU, the FlexCraft uses two off-the-shelf tanks that provide a balanced solution with minimum plumbing complexity. The MMU was designed for a 6 hour EVA however larger FlexCraft tanks offer 20% more nitrogen. A pressure of 3,400 pounds per square inch (psi) was selected so that the ISS version could be recharged on-orbit. Eight 2-pound (lbf) MMU thruster triads achieve similar performance (Figure 10). The propulsion system's wet mass is 67.67 kg.




| Item | Control Authority (deg/s²) | |
|---|---|---|
| | MMU | FlexCraft |
| Roll | 8.77 | 7.05 |
| Pitch | 8.16 | 6.58 |
| Yaw | 8.14 | 5.42 |

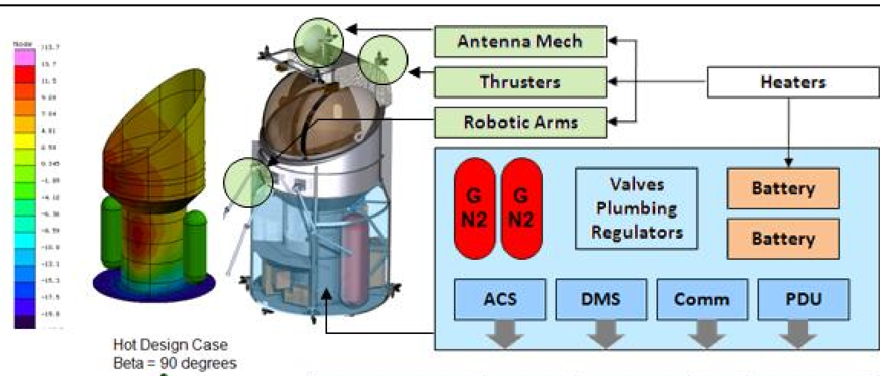


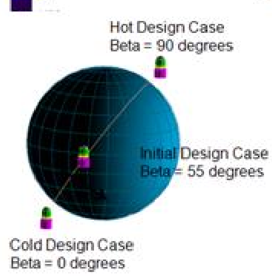

| Component | Qty | Unit Mass (kg) | Basic Mass (kg) | AIAA Category & Code | MGA | Predicted Mass (kg) | Comments/Information |
|---|---|---|---|---|---|---|---|
| Thruster Triad | 8 | 1.41 | 11.28 | A5 | 2% | 11.51 | VACCO 2 lbf cold gas thruster triad |
| Pressure Vessel | 2 | 15.65 | 31.30 | A5 | 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 |
| *Total Dry Mass:* | | | *50.64 kg* | | *3.1%* | *52.20 kg* | |

**Figure 10. The simplest, most effective solution, FlexCraft uses human-rated MMU propulsion.**

*3. Thermal (TRL 9)*

The FlexCraft thermal control system uses space-rated coatings, multilayer insulation, and electrical heater tape to maintain the structure and components within specified ranges for all mission phases (Figure 11). FlexCraft thermal control relies on a cold biased structure achieved using silverized Teflon film on the vehicle's outer surfaces. Avionics are mounted to the vehicle's structure and heat from the flight computer, batteries, and power distribution unit maintain an acceptable temperature environment for the avionics, propulsion tanks, valves, controls, and supply lines located within the avionics and propulsion compartment. Individual heaters are included for the manipulator arm mechanisms, antenna mechanisms, and thruster triads. Where needed, multi-layer insulation (MLI) would be used for thermal isolation and insulation.




| Component | Basic Mass (kg) | AIAA Category & Code | MGA (%) | Predicted Mass (kg) |
|---|---|---|---|---|
| MLI, Thermal Coatings, Tape | 7.5 | E2 | 12.00% | 8.4 |
| Heaters & Thermostats | 2.0 | C3 | 8.00% | 2.16 |
| Thermal Isolators & Conductors | 1.5 | C3 | 8.00% | 1.62 |
| Conductive Thermal Spreader Plate | 10.0 | E2 | 12.00% | 11.2 |
| *Total Dry Mass:* | *21.0 kg* | | | *23.38 kg* |

**Figure 11. Equipment positioning allows passive thermal control**

*4. Electrical (TRL 9)*

Batteries are the simplest and least costly electrical power system for the FlexCraft demonstration mission. Power is provided by twoTRL-9 ABSL Foton M3 Lithium-Ion batteries provide 28-volt power, which is managed by an Advanced Physics Laboratory power distribution unit, which flew on the Mercury MESSENGER mission (Figure 12). The power required for conducting a mission with three propulsion and three manipulator tests is 4,920 Watt-hours (Whr), which is largely driven by communications from the Tracking and Data Relay Satellite System (TDRSS). This is below the Foton battery's 5,400 Whr capacity but represents a demonstrator-unique load because the operational spacecraft will use line-of-sight communications that draws half the power. FlexCraft is well below the payload mass limit for the launch vehicle. Because Foton batteries weigh only 7.5 kg, a four-battery option will be considered to add margin and extending mission life.

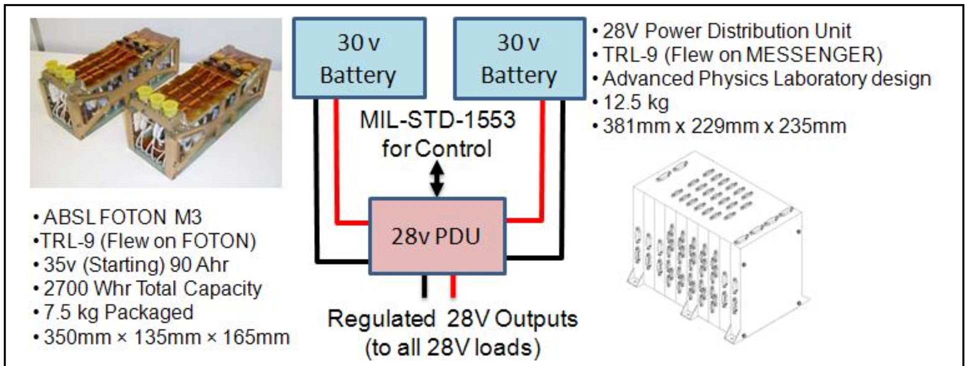



**Figure 12. FlexCraft uses flight-proven electrical power components.**

*5. Avionics (TRL 8)*

Shown in Fig. 13 is the FlexCraft overall control and communications architecture managed by a Space Micro dual 200 Proton computer. This flight-proven computer provides fail-operational redundancy for critical systems while directing the operation of attitude control, communications, manipulators, propulsion, video cameras, and flight test instrumentation. Whereas will use line-of-sight communications the demonstrator is controlled through TDRSS. However, most of the primary avionics hardware has already been identified and is available off the shelf.

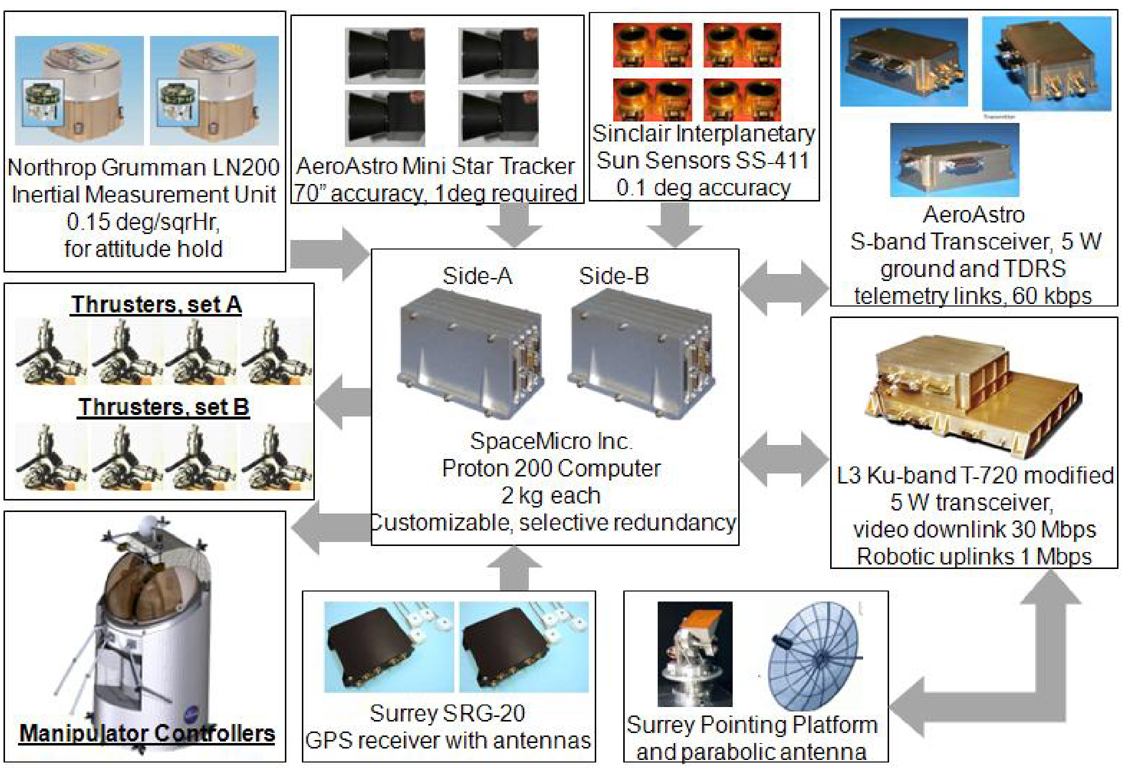



**Figure 13. All Avionics components have flown on other missions.**

*6. Manipulators (TRL 8)*

FlexCraft has three docking stations for interchangeable manipulators and end-effectors. These are positioned to provide maximum visibility for the operator. Although the manipulators may each be different, the demonstrator is equipped with three identical manipulators equipped with end-effectors specifically selected for ISS/satellite servicing and NEO exploration. There will be direct control of manipulators in the human-rated FlexCraft, but because of the Earth-space communications link, the demonstrator operates in a supervised-autonomous mode. As is the case for the operation spacecraft, direct control of manipulators is well understood. The demonstration will assess the interaction of manipulator operations with the propulsion system. Prior to launch, these dynamics will be modeled and simulated then after the mission, they will be compared with test data. Hardware, software and test formulation will incorporate the experience of leading space manipulator experts. Selected through open, competitive procurement the experts are MDA Information Systems and the Space Systems Laboratory at the University of Maryland (Fig. 14).

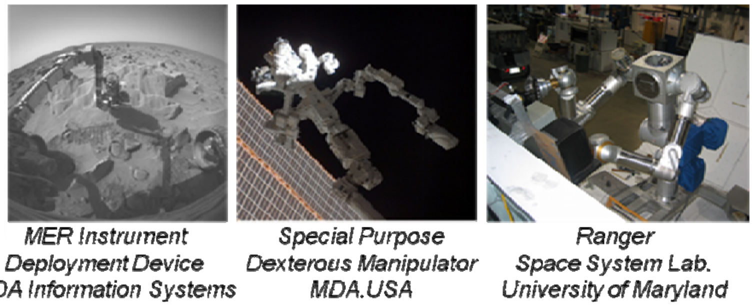
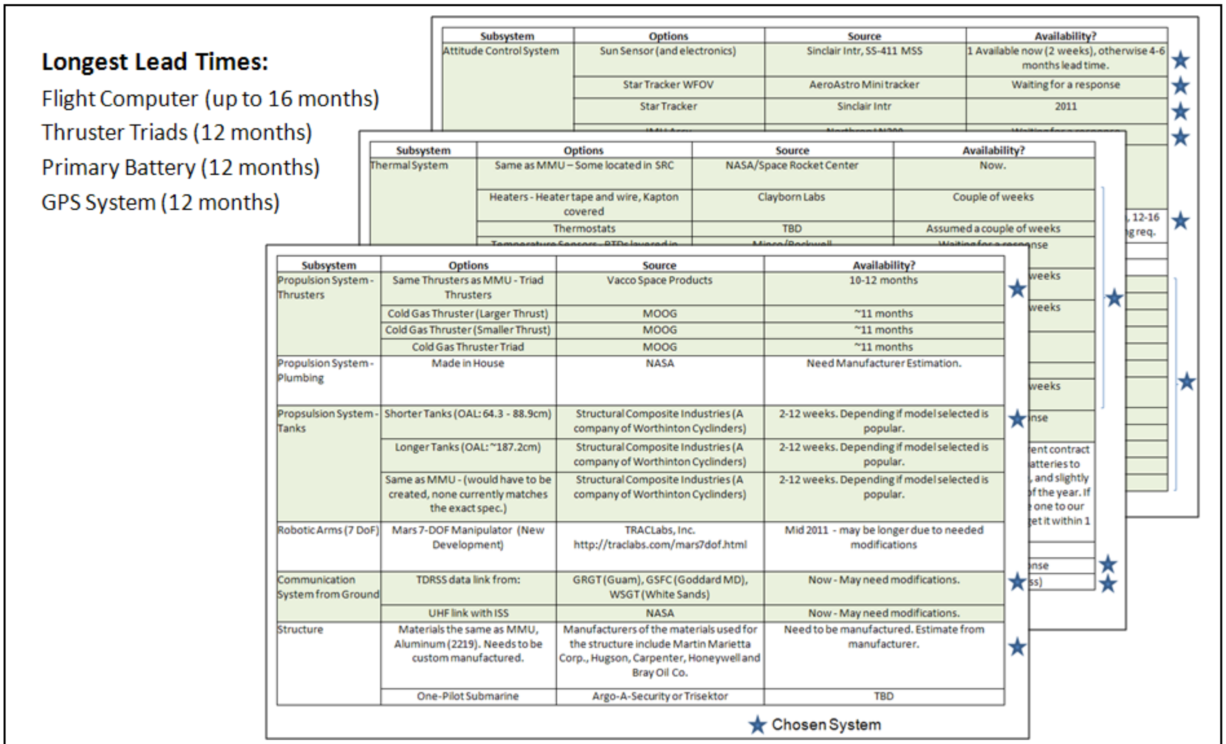



**Figure 14. Team experts have end-to-end manipulator operations in space and subsea environments.**

## III. Parts Availability and Cost

Conventional design, development, test, and evaluation will not support a launch in three years. For this reason FlexCraft uses available systems and parts. To determine availability, vendors were contacted for 90 percent of the components(Figure 15). The longest-lead item is 16 months for delivery a Space Micro, Inc. Proton 200 computer. This works with the schedule, but there will be a continued effort to find alternative parts that may offer more schedule margin or lower cost.




| Subsystem | Options | Source | Availability? |
|---|---|---|---|
| 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 |

**Figure 15. Vendors were contacted to verify delivery lead time**

For FlexCraft, low cost does not come at the risk of meeting mission objectives. Every effort is made to conduct a successful demonstration, however there are creative ways acquire hardware and manage the project that hold cost to a minimum. Table 2 summarizes some of the cost reduction measures.

**Table 2 Methods for reducing FlexCraft cost**

| Cost Reduction | Description |
|---|---|
| **Buy versus Make Hardware/Software** | Avoids cost and schedule risk of Design, Development, Evaluation and Test (DDT&E) |
| **Bare-bones configuration** | Nine systems omitted or simplified for demonstration flight |
| **"Low-cost" launch vehicle** | Lowest cost launch vehicles to accommodate mass, center of gravity and volume |
| **Short mission** | Minimal ground operations cost |
| **Short development schedule** | Forces decisions which results in reduced cost |
| **Small team** | Fewer labor hours |
| **MSFC as prime** | No profit built into labor rates |
| **On-site testing and integration** | Avoids additional cost for shipping flight hardware, travel for test personnel and schedule complexity |
| **Using the existing engineering support contractors** | Avoids additional procurement costs and allows the right skills for the right amount of time |

## IV. Conclusion

Space suits are a logical choice for planetary operations, however for safe, rapid access to the weightless environment, spacecraft offer compelling advantages. Using the same MMU cold gas propulsion system, a spacecraft can service areas on ISS that are inaccessible by suited astronauts. Possibly more important, in case of an emergency, FlexCraft can return from the most distant point in less than a minute. There is no lengthy pre-breathing or risk of bends (decompression sickness) because the spacecraft operates at the same cabin atmosphere as the host. This feature represents a fundamental change to EVA offering short, frequent, and repeated excursions without the 12.5 to 14 hour overhead and "rest day" required for space suit operations. FlexCraft is sized for the entire astronaut population whereas, there are 24 "pressure suits" and 13 life support systems nominally available to support flight. In addition, without the return capability of the Shuttle, astronauts must conduct suit servicing formerly performed by ground technicians. Shirt sleeve operations eliminate fatigue and suit trauma while providing unencumbered access to displays and controls along with hands-in eating and drinking. Interchangeable manipulators are tailored to the mission and provide advantages not possible with gloved tool operations. Furthermore, the spacecraft can be tele-operated for inspections or hazardous operations.

FlexCraft offers a new capability for weightless crew excursions. The good news is that no new technology is required and it has broad utility not only for ISS, but for human asteroid exploration and satellite servicing. Before making FlexCraft operational the propulsion system needs to be tested in the weightless environment. Using existing hardware along with rapid development provides the proper combination for low-cost, on-orbit verification.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