National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

New Technology Report #1662994822

Orbital Workshop Concept

2/1/2023

Inventors: Samuel Dyment, Dr. Kelsay Neely, Andrew Schnell, Luke Scharber

Author: Samuel Dyment

Contents

1.0 Brief Abstract 3
2.0 Contributors 3
3.0 Problem/objective 3
3.1 Objective 3
3.2 Problem 3
4.0 Description 4
4.1 Purpose 4
5.0 Design description 6
5.1 Collector 6
5.2 Example of Recycling Process 8
5.3 Example of Manufacturing Process 9
6.0 Unique or novel features 9
7.0 Commercialization potential 10
8.0 Degree of Technical Significance 10
9.0 State of development 10
10.0 Related technologies 10

1.0 BRIEF ABSTRACT

This is a concept for a system that can perform certain aspects of recycling/manufacturing/integration/servicing in zero-g & low-g space environments. The system consists of a slowly rotating inflatable tube that surrounds a system being worked on. This design captures debris by generating artificial gravity, thereby allowing “dirty” manufacturing/ recycling/ integration/ servicing techniques and enables loading/unloading of large systems. The system encapsulates the piece being worked on and uses an internal robotic arm with appropriate tools. This system is designed to complement the abilities of the Orbital Collector (see NTR 1660756036).

2.0 CONTRIBUTORS

Innovators
Samuel Dyment – MSFC ER41
Dr. Kelsay Neely – MSFC ER41
Andrew Schnell – MSFC ST40
Luke Scharber – MSFC ER41

3.0 PROBLEM/OBJECTIVE

3.1 Objective

Generate a system capable of recycling large systems down to smaller sized scraps for further recycling and to perform large scale manufacturing/ servicing/ integration on-orbit in a safe manner.

3.2 Problem

The material lifecycle is not complete for orbital systems. Components are manufactured on earth and sent into space for their functional life. At the end of their life, they are either abandoned in orbit or are deorbited instead of recycling their materials. Currently orbital recycling and manufacturing technologies are lacking and there are no other options. Additionally, current ground manufacturing and recycling technologies don't work on orbit for several reasons:

1. Gravity is used for nearly all ground recycling technologies
2. Gravity is used for many manufacturing technologies
3. Significant quantities of debris are generated for most manufacturing and recycling technologies. This isn't a problem on earth, but debris generation on orbit is a catastrophic hazard.
4. Most recycling and manufacturing techniques require significant human interaction, which presents a danger for astronauts (EVA's) and is very expensive.
5. Many manufacturing and recycling techniques use fluids, which is impossible on-orbit without pressurized systems.
6. Significant waste is generated during recycling and manufacturing. This waste needs dedicated storage on-orbit.
7. Power requirements are high for manufacturing and recycling, which is difficult to obtain on-orbit.

8. Manufacturing and recycling mechanisms often jam and require servicing. On-orbit the ability to service systems is near impossible.

4.0 DESCRIPTION

4.1 Purpose

The workshop is one of two systems (see the Orbital Collector in NTR 1660756036) necessary to perform orbital recycling and manufacturing. This system deconstructs large systems (Figure 1 step 4A & Figure 7), manufactures large components (Figure 1 step 1 & Figure 8), and assembles/services large systems (Extending Figure 1 step 2 & Figure 8) in a way that captures all debris. This system primarily consists of a large tube or cone that spins slowly relative to its base (see cutaway in figure 2). This cone/cylinder is inflatable so that it can be stowed on a much smaller launch vehicle. The slow rotation serves to collect all debris/scraps on the internal wall of the tube/cone using artificial gravity (see figure 3 for a cross section) both during recycling/manufacturing and while loading/unloading structures (see figure 4). Located on each of the walls are removable storage containers that collect these scraps to be recycled in the other module (can be seen in figures 2 & 3). A method of collection is necessary to move material from the walls into the storage containers, whether it is a conical slope combined with vibration, inflatable feed system, a brush on an articulated arm, or some other design. The base of the system is fixed to a permanent structure, such as a spacecraft or the ISS (see figure 4). The base supplies power and structural support to the system. Any structure being built or disassembled is supported by the base and rotates at the same speed as the tube (see base to rotating systems in figure 5). The tube has a hatch at the opposite end of the base that locks into place within the tube when the opening is not needed. If the tube is rotating, the hatch can open and swing/lock out of the way to allow insertion/extraction of components/systems to be recycled, serviced, manufactured, or integrated (see figure 4). An articulated arm will be necessary for cutting and manufacturing (notional arm design can be seen in figure 2). The ends of this arm may be modular to allow servicing and to save weight/complexity of the initial deployment. Additive manufacturing through wire deposition would be possible with a specific module. This arm would be supported at the base of the structure and the base of the arm would need to rotate with the structure being recycled or manufactured (see figure 5 for base-rotating system). Modules currently identified for the arm are wire deposition additive manufacturing, milling tool, shears, brush, and clamp.

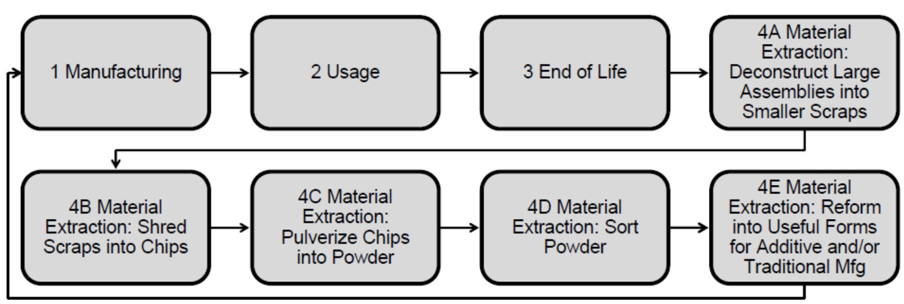

Figure 1: Material Lifecycle

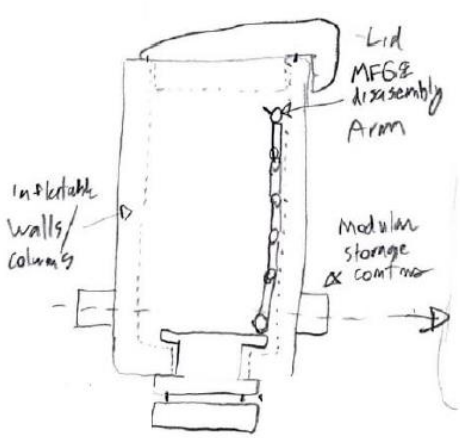

Figure 2: Notional Workshop Overall Design

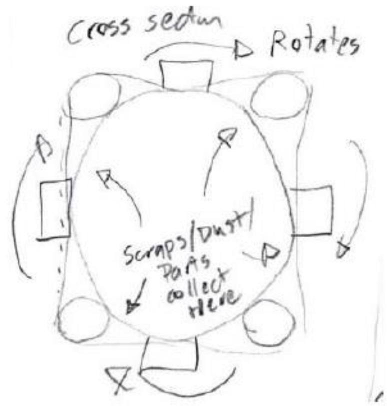

Figure 3: Notional Workshop Design Cross Section

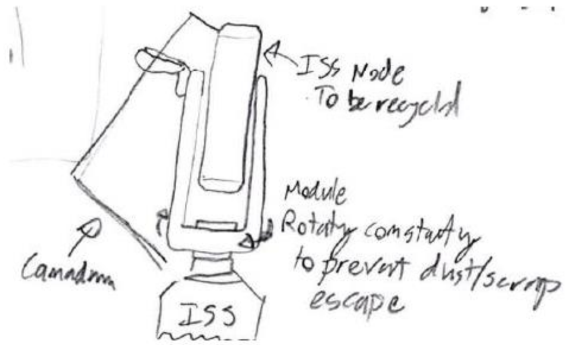

Figure 4: Workshop
Operation – Loading
Component to be Recycled

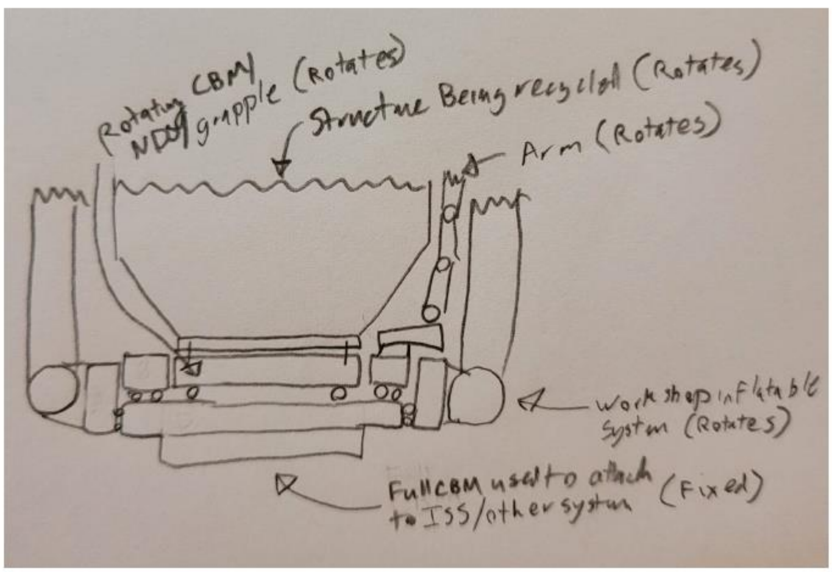

Figure 5: Notional
Workshop Base Design

5.0 DESIGN DESCRIPTION

5.1 Collector

The design consists of 5 main components: base, tube/cone, lid, arm, and workbench.

The base connects the tube, arm, and workbench to other space systems (such as the ISS or another spacecraft) that provides power, data, and structural support (see figure 5).

The tube/cone is an inflatable module that consists of a primary structure and secondary structure. The primary structure consists of two rings connected by four columns (see figure 6).

This could be either cylindrical or conical overall. This is inflated once and does not need to deflate. One ring is attached to the base through a rotating mechanism (see figure 5). The secondary structure includes sheets spanning the columns to collect debris/scraps (sheets are visible in figure 3). Located on each sheet are modular containers & mounts for these containers (shown in figures 2 & 3). The tube/cone likely needs to include some sort of power to attach/detach these modules.

The lid will also be inflatable to save weight (see figure 2). The lid design will be covered in detail in a separate NTR. Basic needs for the lid are the ability to control its position (open and closed) and create a light seal to keep debris in for when the system is not in use or rotating. The lid will need pumps and valves, which will likely be kept on the cylinder near the base.

The arm will be attached to the base, either to the workbench or a system that rotates independently of the tube/workbench (see figure 5). The arm will need to perform multiple tasks, so modularity may be leveraged such that it can perform all the necessary tasks without servicing. The arm will have to perform two main tasks: cutting large systems into smaller parts and to perform additive manufacturing. The arm may also need to perform inspections, traditional manufacturing (milling, drilling, etc.), fastening, and other unidentified tasks. Additionally, it may also need to perform sweeping to move debris along the walls depending on the overall system design.

The workbench serves to hold and rotate systems being recycled and manufactured (shown in figure 5 with a module installed). The workbench needs to provide only mechanical support for various systems, notionally CBM, NDS, and/or CANADARM Grapple. These systems need to also act as bases for new structural components being manufactured. The workbench needs to have the ability to rotate relative to the base.

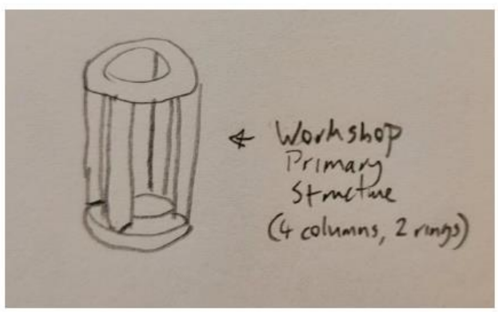

Figure 6: Notional Workshop Primary Structure

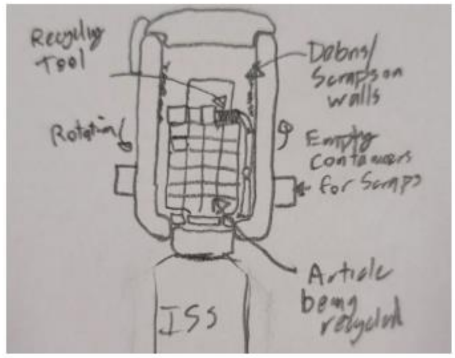

Figure 7: Workshop Operation – System Undergoing Recycling

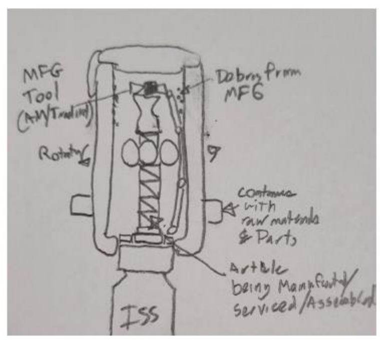

Figure 8: Workshop Operation – System Undergoing Manufacturing/Servicing/ Integrating/Assembling

5.2 Example of Recycling Process

This example process assumes the system is already deployed on the ISS. (Figure 7)

1. The inflatable cylinder is rotated at a slow speed. The arm structure and workbench are static.
2. The inflatable cylinder unlocks the lid, hinges it out of the way, and locks it in an open configuration.
3. A system destined for decommissioning and recycling is carefully fed into the tube by an external arm and is connected to the workbench.
4. The lid's inflatable hinge unlocks, is hinged to the closed position, and is locked closed against the cylinder.
5. The arm, workbench, and decommissioned module begin to rotate with the inflatable cylinder.
6. The arm connects to a cutting tool and begins breaking down the system.
7. Debris/scraps collect on the outer walls as the system is recycled.
8. Debris/scraps are swept into containers by the arm or some other mechanism.

9. The containers are closed after they are filled. These are then removed externally and moved to another module with the capability to turn scraps into forms useful for manufacturing.
10. New containers are placed in the cylinder and the recycling process continues.

5.3 Example of Manufacturing Process

This example process assumes the system is already deployed on the ISS. (Figure 8)

1. The inflatable cylinder is rotated at a slow speed. The arm structure and workbench are static.
2. The inflatable cylinder unlocks the lid, hinges it out of the way, and locks it in an open configuration.
3. A component intended to be a base for a new system is carefully fed into the tube by an external arm and is connected to the workbench.
4. The lid's inflatable hinge unlocks, is hinged to the closed position, and is locked closed against the cylinder.
5. The arm, workbench, and decommissioned module begin to rotate with the inflatable cylinder.
6. The arm connects to an additive manufacturing tool and begins adding metal to the system.
7. Debris collects on the outer walls as the system is recycled.
8. Debris is swept into containers by the arm or some other mechanism.
9. The containers are closed after they are filled. These are then removed externally and moved to another module with the capability to turn scraps into forms useful for manufacturing.
10. New containers are placed in the cylinder and the manufacturing process continues.
11. Additive manufacturing is completed.
12. The arm swaps the AM module with a traditional milling machine.
13. The part is machined as necessary until construction is complete.
14. Containers are attached with components/systems from earth or other MFG modules.
15. The arm attaches these components/systems to the component being built/assembled.
16. When complete, empty containers are placed on the walls & all remaining debris is collected in these containers.
17. The inflatable cylinder unlocks the lid, hinges it out of the way, and locks it in an open configuration.
18. The newly manufactured system is carefully extracted from the tube by an external arm and is disconnected to the workbench.
19. The lid's inflatable hinge unlocks, is hinged to the closed position, and is locked closed against the cylinder.

6.0 UNIQUE OR NOVEL FEATURES

- These techniques have not been adapted to orbital use, so the overall system of performing manufacturing and recycling on-orbit is novel.
- Using a rotation to provide low gravity to collect recycling scraps and manufacturing debris is novel.
- Using rotation to make a dirty system temporarily clean such that it can be opened and loaded/unloaded safely is novel.
- Using an inflatable module to surround large structures is novel.
- Using cargo containers to collect scraps for recycling in other systems is novel.

- Using the ISS as a target and a power source is novel.
- Using cargo containers to load/unload components/systems for integration into other systems is novel.

7.0 COMMERCIALIZATION POTENTIAL

Other companies and government agencies could benefit greatly from orbital recycling and manufacturing technologies.

- The main commercialization potential is the ability to recycle space debris and decommissioned systems (including ISS, spent stages, spacecraft, satellites, and service modules) to save on launch costs & raw material costs as the recyclable materials would no longer need to be launched (note that some systems & fuel would likely need to be launched and integrated on-orbit until orbital manufacturing technologies mature).
- New designs and structures unable to survive earth launch environments would be able to be manufactured on-orbit, opening new avenues for technologies on-orbit.
- Technologies developed for on-orbit use can also be adapted easily to be used on the moon and other planets.
- Recycling technologies are also necessary for reusing scrap materials that are created through manufacturing.
- If debris poses an unacceptable hazard, space debris can be captured and recycled.
- In-situ repairs become possible for deep space missions, increasing reliability while decreasing payload needs.

Additionally, there is significant financial savings to be had in targeting the ISS materials before decommissioning. A rough estimate puts 1 billion dollars of structural materials based on low end launch cost estimates.

8.0 DEGREE OF TECHNICAL SIGNIFICANCE

Major Breakthrough

9.0 STATE OF DEVELOPMENT

Conceptual

10.0 RELATED TECHNOLOGIES

- Orbital Collector NTR #1660756036