SCAVENGING FLIGHT HARDWARE AS A TRANSITIONAL FORM OF NON-VOLATILE RESOURCE UTILIZATION. R.C.Oeftering[1], [1]NASA Glenn Research Center, Mail Stop 86-5, 21000 Brookpark Rd. Cleveland, Ohio 44135

Non-volatile in situ resources are needed to minimize the launch mass of the lunar infrastructure capable of sustaining long term human/robotic operations. Due to the difficulty of extracting and separating the non volatile materials a near term sources should be considered. As an outcome of studies by the Constellation Lunar Surface Systems and Exploration Technology Development Program's Supportability Technology Development Roadmap effort, a new approach has been defined that exploits surplus flight hardware [1]. The approach involves scavenging subsystem hardware and material content from the actual flight vehicles.

The primary role of scavenged hardware is to serve as alternative source for maintenance spares that would normally be provided by logistics payloads. This reduces the payload impact of maintenance by treating portions of the flight vehicle as payload. The lunar missions alternate between uncrewed cargo and crewed landers [2]. The cargo landers have complete systems available and thus they become the main source of scavenged hardware. The importance of scavenging to program supportability is expected to drive new design requirements for common interchangeable, reconfigurable systems.

Operations on the lunar surface environment are expected to cause very high levels of equipment wear and tear. The risk for damage is much greater than on the International Space Station and both mitigation and repair technologies are needed to sustain operations. The supportability technology roadmap study determined that the root cause of many mechanical problems is relatively minor abrasion damage to surfaces that, left untreated, can result in mechanical system failure or loss of critical resources. Surface damage is particularly critical for assemblies with mechanical bearings and for sealing surfaces like hatchways and fluid connectors. Though mitigation techniques may extend hardware life inevitably maintenance and repair operations are needed to restore surfaces. The need to restore surfaces or replace parts thus drives the need to employ repairable, scavengable and reusable materials in the construction of the vehicle.

The ability to scavenge and reuse the flight vehicle hardware or material depends on embedding certain features in the initial design and manufacturing processes. For example avionics units can be designed to be reconfigured by a combination of software and reconfigurable hardware. To scavenge electronic components the designers must carefully select packaging and encapsulation methods that do not impede access. Though external equipment cannot be entirely eliminated, minimizing the external equipment by embedding key features is essential to successful maintenance and scavenging.

The supportability roadmap took the unusual step of establishing a supportability strategy with the goal of establishing a high level of resource independence [3]. It is envisioned that careful selection of technologies would minimize the dependence on Earth supplied resources. The reasons for this strategy are twofold; one is to minimize the cost of supporting long term operations; second is to demonstrate a resource independence capability that would be essential to Mars missions. To achieve early resource independence it is necessary to impose guidelines on the technology selection process. Therefore, the supportability technology roadmap includes a set of technology selection criteria. The criteria serve as a way of evaluating technologies beyond the simple size, weight and power criteria used for flight hardware.

Beyond scavenging for maintenance applications the supportability strategy also considers how scavenging can be used to expand the lunar architecture. This includes ISRU applications. In the case of a permanent lunar outpost, repeated missions by crewed landers and cargo landers results in an accumulation of hardware. Once the primary activity of building an inventory of spares is satisfied then secondary applications follow. Secondary applications can include repurposing hardware for new applications that expand the power, communications, crew support infrastructure and supportability functions. For example, a surplus flight computer can be reconfigured to control a power system, serve as a controller for maintenance or fabrication equipment or even control various ISRU processes.

Initially high level assemblies or Lunar Replacement Units (LRU) are scavenged because they are most easily employed with little external equipment. As time passes however the growth in inventory and the cycling of worn out equipment begins involve lower level assemblies and single components. For example a damaged avionics box is usually disabled by only a few components while the majority of components are still good. Low level scavenging provides spares to restore higher level assemblies.

These low level components can also be used to construct new applications where in situ fabrication processes and scavenging converge. That is, material resources scavenged from the lander combined with individual components or sub assemblies can be combined to create new applications. Although the metals used in this case are from the lander the fabrication process would also apply to same material derived from lunar resources.

The approach harkens back to a concept introduced in 1980 by Freitas where ISRU resources are combined with specialized high value components referred to as “vitamin technology”[4]. Small components and subassemblies may be imported from Earth, however many can be scavenged by the flight vehicles that are already there.

Production of new hardware exploits the advances in Free Form Fabrication (FFF) technology. Electron beam based FFF, is a particularly powerful technology because it is efficient, flexible, and innately space compatible [5]. By pre-encapsulating hardware one can structurally integrate complex mechanisms into FFF produced housings. It may then be possible to fabricate large robotic equipment for ISRU mining applications.

FFF fabrication typically produces a rough casting like product that requires a post process machining and grinding the produce the finished product. Large machine tool technology is very unsuited to the lunar environment and would be very expensive to deliver. To avoid the post process machining problem the supportability technology roadmap described a way of advancing FFF fabrication by integrating different forms of material delivery (solid powder, liquid droplets, and metal vapor) and by introducing ion beam technology.[6] The material transport technologies and ion technology, coincidently, are the primary techniques for repairing surface damage. Thus the program can exploit the synergy between repair and fabrication.

Development of a “Progressive Refinement” approach to Free Form Fabrication represents one of the potentially greatest advances in manufacturing technology in decades. This approach also allows the program to use surplus hardware to build an in-situ based infrastructure without the delivery of massive equipment. Further, when ISRU metals become available then operations can be scaled up to point where ISRU materials can be exported.

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