National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

December 5, 2012

Reply to Attn of: Satellite Servicing Capabilities Office

Subject: An Open Letter to the GEO Satellite Community

Since NASA's May 2012 Satellite Servicing Workshop, several members of the geosynchronous Earth orbit (GEO) satellite community have asked the NASA Satellite Servicing Capabilities Office (SSCO) whether a list of specific "cooperative servicing aids" exists: that is, features that could be incorporated into new satellites to facilitate servicing in the future.

The many inquires we have received for such a list underscore the relative novelty of the concept of GEO satellite servicing, yet also highlight the high level of interest in this promising new capacity. More than twenty new satellites arrive in GEO each year. However with no servicer ever having been in GEO, there has been little cause for satellites to be built with cooperative servicing aids. But as news reports and conference panels show, times are changing.

There is growing movement toward realization of on-orbit satellite servicing, and with it, a pending shift in the lifecycle of GEO spacecraft. This pending paradigm shift requires proportional complementary forethought and action on the part of potential "future clients" and those who support them: international institutions and agencies, satellite manufacturers, fleet owners and operators, insurance providers, and fledgling service providers. Taking concrete steps to define and place servicing aids on these new spacecraft will ensure that the entire community can collectively reap the full benefits that the emerging servicing industry offers. The GEO satellite community has an opportunity now to collectively define these servicing aids and start including such cooperative features onto spacecraft being designed and manufactured today.

Building from our body of experience in human and robotic servicing, our NASA team has accordingly compiled the following set of cooperative servicing aids for consideration by the community. Every servicing mission that we have investigated and executed – beginning with the Solar Max repair, continuing through the Hubble Space Telescope servicing missions, and now developing a concept for a GEO servicer – has brought us to a recognition of specific aids that would have made the task cooperative, and therefore easier. That thought process is reflected within the list.

Recognizing how many factors are involved in any endeavor, this list was created not as a mandate and certainly not as a dictate, but rather as a starting point for discussion among the many diverse stakeholders eager to establish a servicing-enabled future. We are posting this information publicly to ensure that the entire aerospace community, and not just the individuals who requested this list of aids, has equal access to this information.

You will find that the table is organized based on the level of impact these features would have on existing spacecraft designs and manufacturing. This was done purposefully. All would agree that it would be foolish to suggest to a manufacturing team that they redesign hardware already on the production floor to accommodate a 20-kilogram grapple fixture (equivalent to that installed on Hubble in the 1980's). Instead, we would advocate for the polar opposite.

We believe that the community should focus first on the servicing aids that cost next to nothing, weigh next to nothing, and require no additional analyses. The first example would be closeout photos taken with servicing in mind. Another easily implementable aid would be the use of Velcro instead of tape to close out the multilayer insulation covering a fill-and-drain valve. As these are adopted or perhaps even eventually mandated by insurance underwriters, the next logical steps would be to focus on aids that require accommodation earlier in the design cycle of a spacecraft, such as new, servicing-friendly fill-and-drain valves.

The conversation is not intended to stop here. Our Goddard team has reached out to organizations that might be willing to host, foster, and draw together the community to expand future interchange on this topic. We will keep the community updated as these discussions progress. In the meantime, our team welcomes any input and questions you may have at Agency-Satellite-Servicing@mail.nasa.gov, and we encourage you to share this information with others who may be interested. Please visit http://ssco.gsfc.nasa.gov for SSCO updates on this topic.

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Enclosure

Proposed Spacecraft Bus Servicing Features to Facilitate On-Orbit Robotic Satellite Servicing in Geosynchronous Earth Orbit

	Level of Spacecraft Bus Modification		
	Low: Exterior Additions	**Medium: Minor Modifications**	**High: Redesign and Design**
Rendezvous and Proximity Operations	Add optical/reflective target on docking/capture axis (adhesive decal) Do not remove optical positioning aids used on the ground Take closeout photos using LIDAR or infrared Take additional closeout photos of aft end of spacecraft at launch site with servicing in mind Provide detailed as-measured dimensions of flight ready system (with blankets, etc.) Provide network access to closeout photos (archive with searchable keywords)	Install hemispherical retroreflectors for long-range targeting by the Rendezvous and Proximity Operations (RPO) sensors Add solar-powered LED beacons Add truncated-cone navigation aid (to provide pitch and yaw information) Install specific servicing sensors with telemetry (thermocouple on the fill-and-drain valve [FDV] mounting plate)	Add omni-directional, low-power radio frequency (RF) beacons Add external status indicator to visually indicate spacecraft readiness for capture Add RF crosslink that provides range information Add aperture door to sensitive optics to prevent contamination during servicing
Capture	Add reference markings around Marman ring (clock-face tic marks) Standardize blanket dressing around Marman ring (trim existing blankets) Take additional closeout photos of Marman ring (and surrounding area) at launch site	Standardize Marman ring (for capture with a gripper tool) Establish spacecraft servicing mode in flight software Add external grounding point to equalize electric potential between spacecraft Analyze deployables to accommodate on-orbit loads (thermal & mechanical)	Add grapple features on the spacecraft bus aft end Add standardized docking feature Design deployables to accommodate on-orbit loads (thermal & mechanical)

Proposed Spacecraft Bus Servicing Features to Facilitate On-Orbit Robotic Satellite Servicing in Geosynchronous Earth Orbit, continued

	Level of Spacecraft Bus Modification		
	Low: Exterior Additions	**Medium: Minor Modifications**	**High: Redesign and Design**
Refueling	Standardize loop size and color (to maximize contrast) of safety wire Add external labels that identify location of the FDVs and their respective species Certify FDV design for use without tertiary caps Perform analysis of solar array shadowing Take additional closeout photos of FDV (and surrounding areas) at launch site	Increase FDV body strength to eliminate the need for a backing wrench Standardize FDV diameter size, shape, and finish Install robotically compatible "quick disconnect" on FDV prior to launch Add contrasting color to FDV mounting plate Utilize servicing-compatible safety caps	Redesign FDV to be compatible with robot interface (e.g. Orbital Express design) Add a normally-open pyro valve upstream of fuel/oxidizer tank fill valve Carry additional helium pressurant Design and install servicing-compatible antennas Design and install servicing-compatible solar arrays Add accessible FDV for electric propulsion system Add additional solar array gimbal axis Add onboard high-accuracy flow meter Add additional antenna gimbal axis
Repair	Close thermal blankets with Velcro only; do not use tape or stitching Add Velcro to back of all existing thermal blanket flaps to hold them open Provide loops on thermal blankets to facilitate manipulation with robotic arm	Add external cameras to observe all deployments in case of anomaly Design thermal blanket flaps (with Velcro on back) for all external interfaces	Design deploy mechanisms with external robotic overdrive feature (hex drive)

Proposed Spacecraft Bus Servicing Features to Facilitate On-Orbit Robotic Satellite Servicing in Geosynchronous Earth Orbit, continued

	Level of Spacecraft Bus Modification		
	Low: Exterior Additions	**Medium: Minor Modifications**	**High: Redesign and Design**
Component Replacement	Add thermal blanket flap over existing ground test ports Add external labels that identify location of the ground test ports	Add external connector that provides access to major spacecraft bus systems Position ground test ports at aft end (or area that robotic arm can easily access)	Incorporate modular design for unit replacement Add external orbital replacement unit (ORU) interface with power and data connections Combine mechanical and electrical connectors (blind mates)
Remote Survey	Add external visual markings to identify satellite name (ID number)	Add retroreflectors to tips of antennas and solar arrays	