2019 GLOBAL SATELLITE SERVICING FORUM

Forum Sessions will begin 0900 EDT
Welcoming Remarks:

Brian Weeden
Jim Armor
Michael Leahy

0900 – 0930 EDT

TO SUBMIT QUESTIONS

Go to: https://www.sli.do/
Enter Event Code: #X096

TO CONNECT TO WIFI:

Wi-Fi Username: FHI360CONFCECN
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Spotlight Talk: Joe Anderson, SpaceLogistics LLC.

0930 – 0945 EDT

To submit questions, go to: https://www.sli.do/
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SpaceLogistics
Pioneering the Future of Space

October 2019

Presented by: Joe Anderson
Vice President, Business Development and Operations

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Space Logistics, LLC
A Northrop Grumman Strategic Venture

CURRENT STATUS
- A Wholly Owned Subsidiary Of Northrop Grumman
- MEV-1
  - 5 Year Service Contract – Intelsat
  - Launch Period: October 2019; ILS
  - FCC and NOAA Licenses Issued
  - L+1 Insurance Placed
- MEV-2
  - 5 Year Service Contract – Intelsat
  - Launch Period: Early 2020; Ariane
  - Build to Print of MEV-1

Service Offerings
- Station Keeping
- Incline Reductions
- Relocations
- Inspections

Value Proposition
- Defer Capex
- Start New Orbital Roles
- Capitalize On Old Assets
- Anomaly Attribution

MEV Docked Life Extension
Making Commercial Satellite Servicing a Reality in 2019
MEV-1 Launch Site Preparations
Next Generation Life Extension

Mission Extension Pods (MEP™)
- Propulsion Augmentation Using EP
- 6 Years Life Extension (2000kg Client)
- Fast & Simple Install to LAE
- Self Contained Power
- Self Contained Telemetry & Commanding
- Removable

Mission Robotic Vehicle (MRV™)
- Installs MEPs Into Client LAE
- Built on MEV Heritage
- Full MEV Capabilities
- Adds Simple Robotics

Low Risk – Low Cost Life Extension; Built on MEV Heritage
Demonstrating the Fundamentals of In-Orbit Assembly
SpaceLogistics
Pioneering the Future of Space
Delivering
Economics of On-Orbit Servicing Part I: Commercial Servicing Pitch Session

0930 – 1020 EDT

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Michael Pollack
Vice President for North America, Effective Space Solutions
IN-ORBIT SERVICING: GEO, BELOW AND BEYOND

MICHAEL POLLACK
EFFECTIVE SPACE
GSSF
OCTOBER 2019
“in-orbit servicing is.. ripe for growth, providing the satellite industry with an attractive value proposition”  (NSR In-Orbit Services report)
NSR: GEO accounts for 75% of total In-Orbit Servicing revenues over next decade

our ‘phase one’ deployment: extending the life of GEO satellites in orbit
our SPACE DRONE™ spacecraft will rendezvous and dock to aging GEO satellites

and can be further adapted to GEO debris removal by adding robotic capabilities
Effective Space is pioneering last-mile logistics in space, deploying and operating a fleet of small SPACE DRONE™ spacecraft

- 525-600 kg, 1m x 1m x 1.25m
- Ride-share capable for easier launch
- Launch to GTO or GEO

‘Phase One’: providing docked life-extension services to operators of satellites in GEO, de-orbiting, relocation services

Next phase: active-debris-removal and post-mission-disposal for LEO constellations

Future phases: in-space logistics, space exploration
Leveraging GEO program to support LEO constellations with active debris removal and post mission disposal by introducing a LEO servicing spacecraft
True Disruption from the Norm

Disrupting old models via market innovation:
• Porting customers from CAPEX to OPEX
  • life-extension fees << replacement cost
• Reducing customer’s market growth risks
• Enabling satellite ‘second-hand’ market

Disrupting via technology innovation:
• Design-to-cost small spacecraft platform
• Rideshare launch → attractive opportunities
• Proprietary non-intrusive simple docking
• Up to 18 years of mission life

Disrupting via business innovation:
• High-margins service company
• Eco-system of leading partners/suppliers
• Fully insured in-orbit servicing missions

COMMERICIALLY VAILABLE
IN-SPACE ROBOTICS
READY SOON
Talbot Jaeger
Founder and Chief Technologist, NovaWurks
Servicing Business Case (Profit) – Function(Costs, Opportunities and Client)

- Costs are key parameters (NRE, RE)
- Opportunities are also key
  - Driven by perceived value of clients
  - Driven by spacecraft
Some LEO Servicing Spacecraft Drivers

• Expendables (mostly low duty cycle)

• Life/Replacement Costs and Plan/Strategy
  • Also affected by Launch Service price competition

• Spacecraft Price/Quality
  • Bulletproof “Class A”
  • Automobile (Safe and Cost Effective)
  • Cubesat
“Automobile” Space Parts: Increase The ‘Opportunities’ for Service Through Separable Systems

Give Payloads Separable Space Serviceable I/Fs

Re-configurable and Re-useable
Enable Prolific On-Orbit Payload Assembly and Service

Mass Produced Support Block and I/F (Intelligent Blocks)

Automated Quality I/F Support and Cost Efficiencies

Ground Assembly And Launch

Space Assembly
A Serviceable Space Eco-System
Developmental Efforts Opening Up The Space Sector

On-Orbit Robotic Assembly/Servicing

Self-Assembly
Ron Lopez,
President & Managing Director, Astroscale U.S.
Space is becoming unsustainable
Space Debris Growth Trends

Source: European Space Agency, presentation of H. Krag, Head of ESA's Space Debris Office at SWF Summit for Space Sustainability, June 26, 2019

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Approximately 20-100 satellites per year will require de-orbit servicing.
## Orbital Debris Removal Services – Market Segments

<table>
<thead>
<tr>
<th>Services</th>
<th>End of Life (EOL) “Don’t add any more debris”</th>
<th>Active Debris Removal (ADR) “Remove debris that is already there”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Potential Customers</strong></td>
<td>Constellations, Private Satellite Operators</td>
<td>Governments, International framework</td>
</tr>
<tr>
<td><strong>Client Objects</strong></td>
<td>- Failed satellites</td>
<td>- Environmentally critical objects</td>
</tr>
<tr>
<td></td>
<td>- 50~500kg</td>
<td>- 500kg+ (up to tons)</td>
</tr>
</tbody>
</table>
| **Rationale & Metrics**  | - Risk Mitigation: Business Continuity and Liability Reduction  
  --Number of dead satellites in orbit  
  --Failure Rate  
  - Regulatory Compliance  
  --Post Mission Disposal (PMD) Rate  
  --Time from failure to de-orbit | - Assure spaceflight safety for all operators                       |
|                          |                                               | - Demonstrate commitment to orbital sustainability               |
| **Global Responsibility**|                                               |                                                                 |
| **Solution Type**        | Semi-cooperative approach and capture          | Non-cooperative approach and capture                              |
Notional example assuming a 95% PMD rate target with a 97.5% trigger threshold

Year 6: 18 sats removed
Year 8: 16 sats removed
Year 11: 16 sats removed

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Debris Removal Services

Get peace of mind for an affordable rate!
with the world’s leading debris removal provider

Get started

Why choose Astroscale debris removal services?
Our proven technology protects you from satellite collisions, debris impacts and failures

We successfully performed the first mission to remove space debris (ELSA-d)
We can de-orbit the majority of failed LEO satellites*
We established the UK National In-Orbit Servicing Satellite Control Centre
Astroscale’s international team bring a wealth of experience

About our Debris Removal Services

What is debris removal?
We can safely de-orbit failed satellites to a low altitude where they decay naturally.

Add Options
• Fast track
• Target assessment report
• Consulting services

Satellites we cover:
• Standard: 50-300kg
• Next Gen: >300kg
• Bespoke service for larger satellites

Assessment of target viability required

* Assessment of target viability required

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Resources to Execute Business Plan

- USD $136M raised (as of August 2019)
- 90+ employees

Growing Team, Increased Fundraising and Expanded Global Presence

- A: $7M
- B: $20M
- C: $27M
- D: $50M
- D2: $32M

- Funds raised: $136 million
- Global staff: 90+ people

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Reaction Panel

Moderator: Sima Fishman, Managing Director, Euroconsult USA

Bryan Benedict
Senior Director, Innovation & Satellite Programs, SES Government Solutions

Earl Han
Engineer, OneWeb
Morning Coffee Break

Sessions Resume at 1100 EDT
Economics of On-Orbit Servicing Part II: Panel Discussion

1100 – 1200 EDT

Moderator: Joerg Kreisel, CEO, JKIC

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Carla Filotico
Partner, SpaceTec Partners
OOS/ ADR Market Highlights

Global Satellite Servicing Forum, Washington DC, October 2019
Due to the growing number of satellites in LEO, forecasted collisions are expected to grow dramatically, especially at lower PMD compliance rates.

Projections of cumulative number of collisions in LEO assuming different scenarios

- **90% PMD compliance of satellites**, with a mega-constellation operational in 2020-2070 deorbiting with a 50% success
- **90% PMD compliance of satellites**, explosions with a mega-constellation operational in 2020-2070 deorbiting with a 95% success
- **90% PMD compliance of satellites with a mega-constellation operational in 2020-2070** deorbiting with a 90% success
- **Current PMD compliance of satellites (no mega-constellation)**
- **90% PMD compliance of satellites (no mega-constellation)**

\[PMD= \text{Post Mission Disposal} \; ; \; \text{Source: ESOC Debris Office}\]
It is crucial that both actions of applying Space Debris Mitigation (SDM) measures and removing dangerous debris are implemented ASAP.

Studies done by ESA (and NASA) showed, that the removal of as few as 5 of the highest risk objects (defined as mass per probability of collision) per year from LEO can stabilise the long-term LEO debris environment. The sooner that starts to happen, the better, as this would enable the reduction of potential exponential increases in debris.

It is important to first stop creating new debris (with stricter compliance to and higher success of the implementation of the SDM requirements), and then act on the defunct dangerous debris.

Sources: Strategies for active removal in leo, B. Bastida Virgili, H. Krog, ESA space debris office; Active Debris Removal – A Grand Engineering Challenge For The Twenty-First Century, J.-C.Liou, NASA
OOS market is driven by the need to mitigate the issues of space debris, as well as by the need to extend satellite lifetime and reduce upfront CAPEX.

**Examples of key OOS/ADR services/missions**

- **De-Orbiting**
  - Move of target to graveyard orbit or initiation of destructive re-entry

- **Salvage**
  - Salvage of target to e.g. orbital station or re-entry (non-destructive) to earth

- **Robotics**
  - **Repair** - Diagnosis and correction or repair of failures or faulty units of the target
  - **Retrofit** - Upgrade, update or exchange of orbital replacement units (ORUs) on the target

- **Life Extension**
  - **Maintenance** - Re-fueling or other re-supply of the target
  - **Docked Inspection** - System and fault diagnosis of the target using physical connectors
  - **Remote inspection** - Remote system and fault diagnosis of the target
  - **Re-orbiting** - Move of target to/in its target orbit

- **Active Debris Removal**
  - Removal of defunct space objects
The OOS/ADR global total addressable market is expected to reach between 2.5 and 5 billion Euro by 2036.

**Estimated Forecast of IOS/ADR Global Total Addressable Market (TAM)**
(2017-2036, € Billion, yearly cumulative revenues)

- **Low case**
- **Medium Case**
- **High Case**

Based on missions to date

Source: SpaceTec Partners analysis on NSR, Technavio, ESA and ADR/OOS market literature
The higher market estimate is driven by the ‘global’ action of performing 5 ADR missions per year

OOS/ADR Revenues by Type of Service
(Cumulative 2036, Low Case)

- Total in 2036: €2.5 B
- No commitments to perform ADR at global level

OOS/ADR Revenues by Type of Service
(Cumulative 2036, High Case)

- Total in 2036: €5.0 B
- Overall commitment to remove 5 dangerous defunct debris per year. Pushed by regulation? International Agreements? Own self-consciousness?

Source: SpaceTec Partners analysis on NSR, Technavio, ESA and ADR/OOS market literature
SpaceTec’s Sweetspot - “Where space meets business”

Dedicated team of 20 professionals with 16 nationalities, 15 languages

Offices in Munich and Brussels, hubs in London and Vienna
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