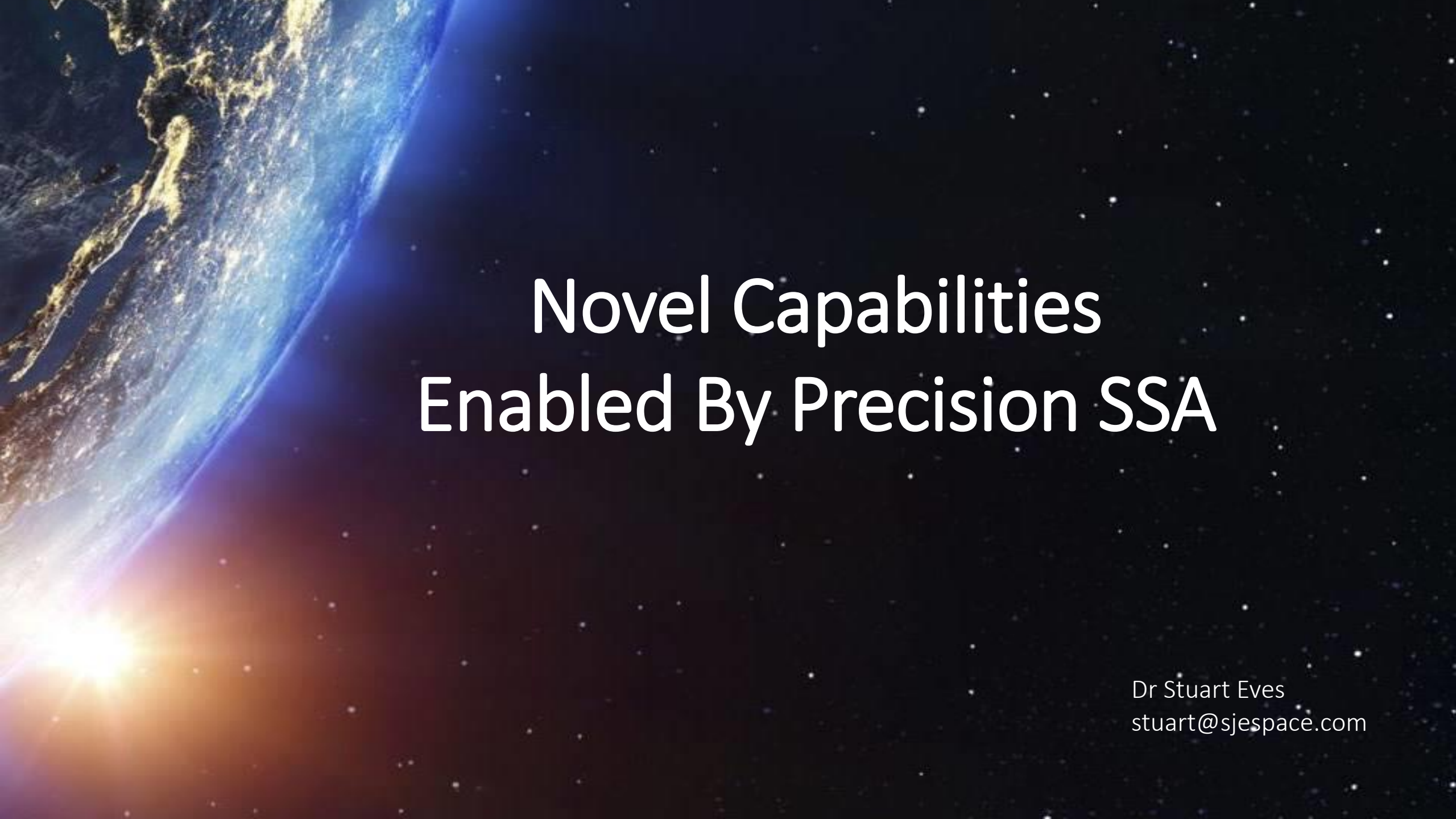

Novel Capabilities Enabled By Precision SSA

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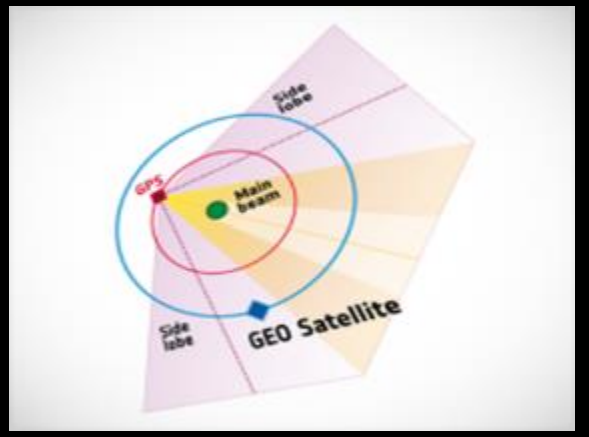
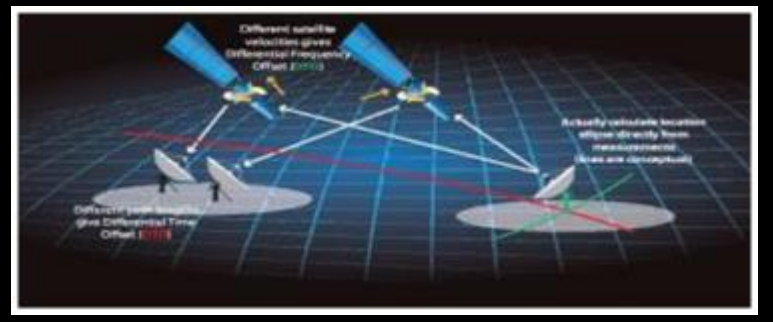
Novel Capabilities Enabled by Precision SSA

- Increased satellite lifetimes and duty cycles
- Companion satellites and synergistic surveillance
- Regional navigation using time-tagged signals
- Bi-static regional surveillance and weapon targeting
- SIGINT
- Rapid inter-satellite link applications
- GNSS monitoring
- Very high capacity, extremely resilient communications via satellite clusters
- Satellite servicing and on-orbit assembly
- Debris detection/removal/reprocessing



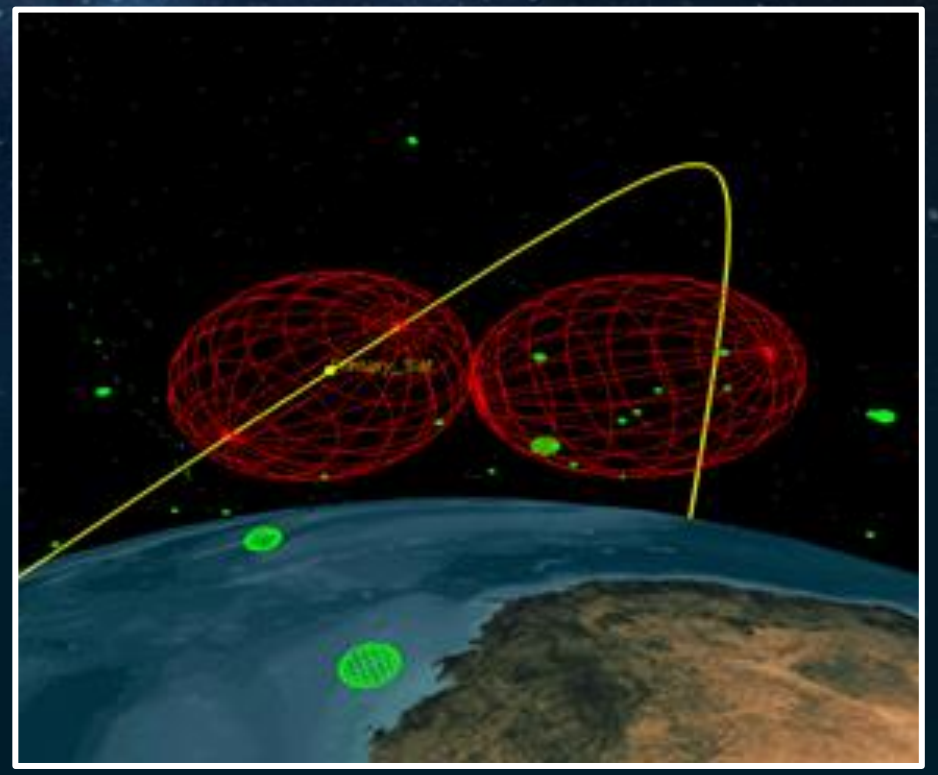


Increased Satellite Duty Cycles and Lifetimes

- More accurate tracking is essential to avoid operators becoming overwhelmed by conjunction warnings as catalogue sizes increase

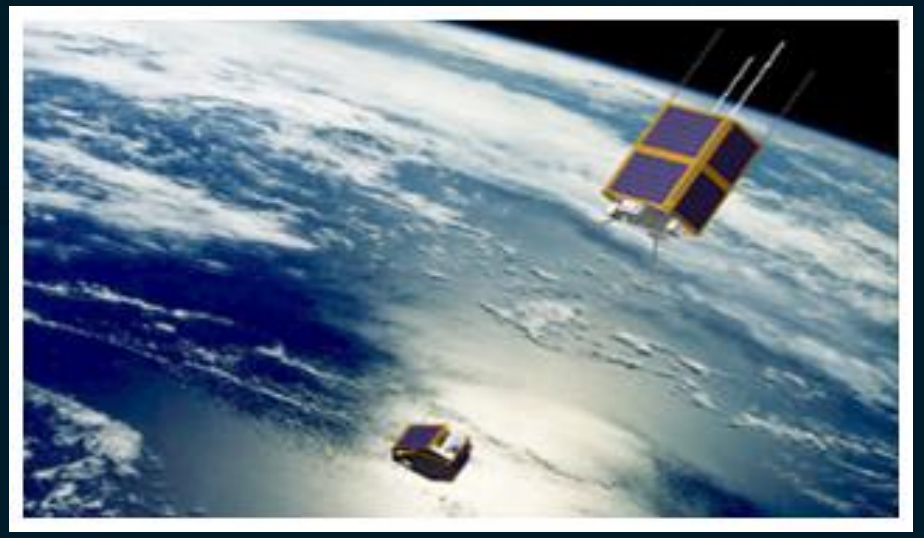
- Improved tracking will permit satellites to save propellant by adjusting their orbits only when conjunctions are known to be very close

- Avoids unnecessary interruptions to operations and extends the satellite lifetime

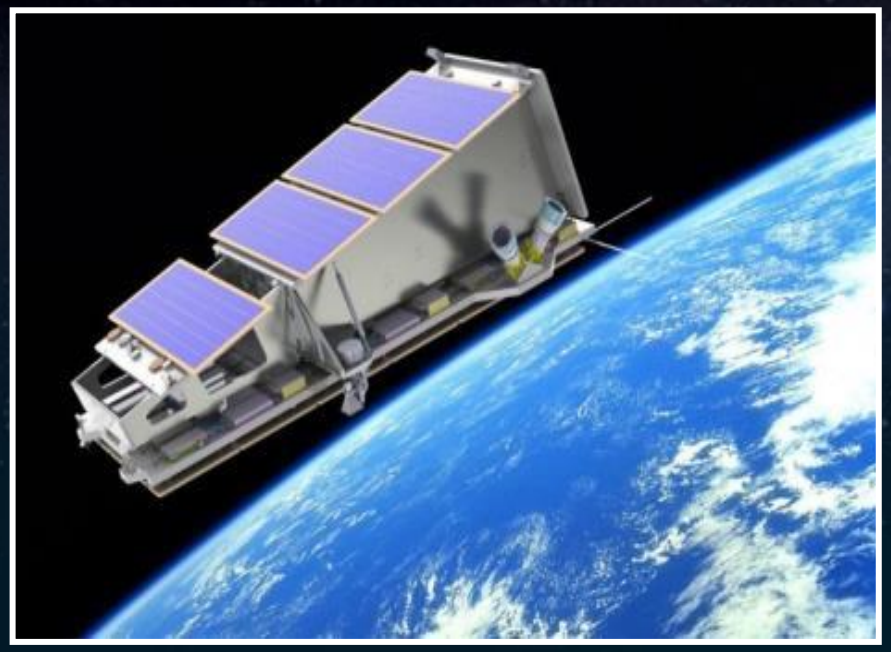


Companion Satellites

- Concept proposed by US in November–December 2014 Air & Space Power Journal
- Envisages companion satellites that monitor potentially hostile satellites in LEO
- Concept assumes monitoring of enemy satellite pointing; transponder activity; manoeuvres; etc.
- Analogous proximity operations are already happening in GEO
- This is risky if the quality of the SSA is low



Synergistic Surveillance

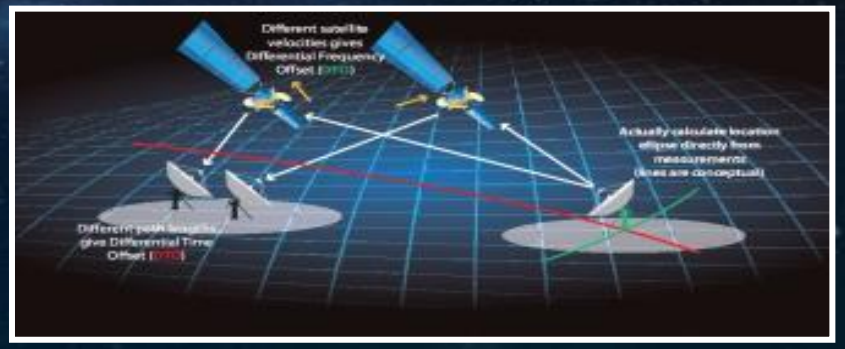


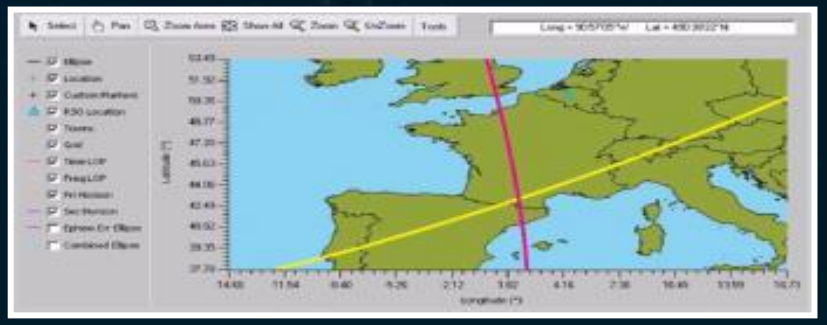
- Synergistic surveillance concept
- Four pairs of satellites
- Each pair consists of one SAR and one optical satellite

- SAR carries AIS and a cloud sensor
- Inter-satellite link allows SAR to cue optical satellite to avoid clouds
- Precision SSA facilitates this concept

Navigation Concept

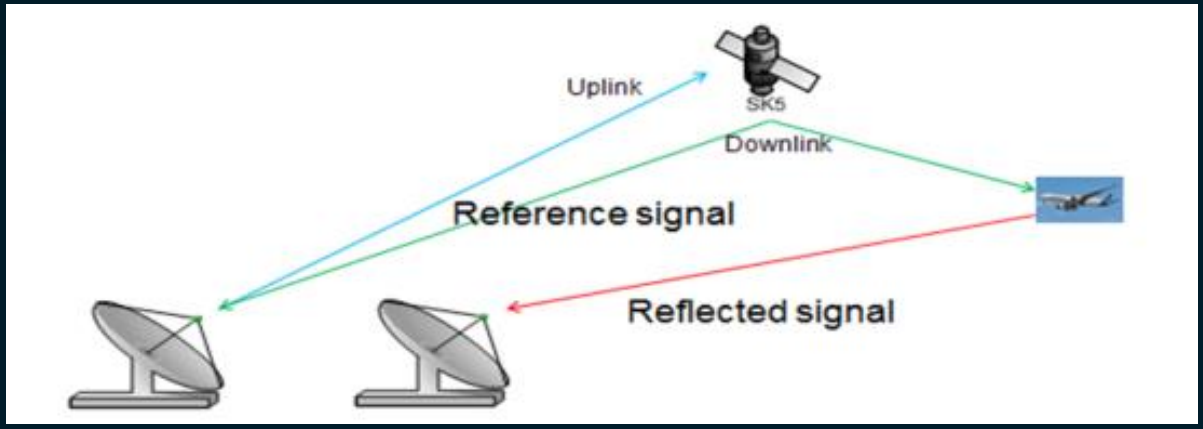
- A GEO system could be used to provide a navigation function using a technique which is essentially the inverse of the Sat-Id approach which is used currently to geo-locate sources of interference
- A signal broadcast via two (or more) GEO satellites from a well-surveyed location in the home nation could be received and processed by a user terminal
- The “time-difference-of-arrival (TDOA) and “frequency-difference-of-arrival” (FDOA) of the signal via the two satellites allows two arcs to be plotted on the surface of the Earth; their intersection is the location of the user terminal





Passive Bi-static Surveillance

- The (spot-beam) signals from GEO satellites could be used as the illuminator for a bi-static surveillance system to detect large vehicles and aircraft.
- The feasibility of such a system to detect moving targets has been demonstrated using a GEO satellite broadcast
- The advantage of using the GEO signals, rather than a transmitter of opportunity in theatre, is that the owner would have control over the illuminating signal , and would be able to use existing ground segment hardware



Next generation GEO communication satellites could also have a surveillance role

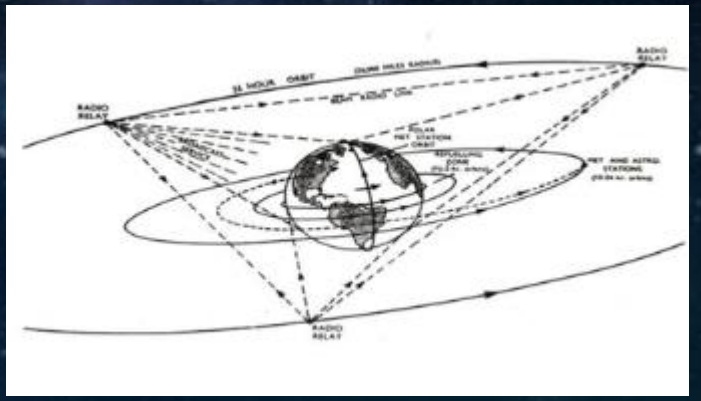
SIGINT

- Combining the output from the receive antennas on more than one satellite, it would be possible to geolocate sources of communications interference
- It would also potentially be possible to exploit comms signals in adjacent bands by transponding and processing signals intended for other satellites
- The accuracy of the system will again depend on the quality of the SSA

Not all interference is accidental!

Long-Range Inter-satellite Links

- Systems such as the European Data Relay Satellite (EDRS) will increasingly help to establish a "space wide web" of links between satellites
- This will allow commands to be sent, and data to be returned from satellites, in tactical timeframes
- Links to RPAs can be established too
- Precision SSA will shorten acquisition times and save money



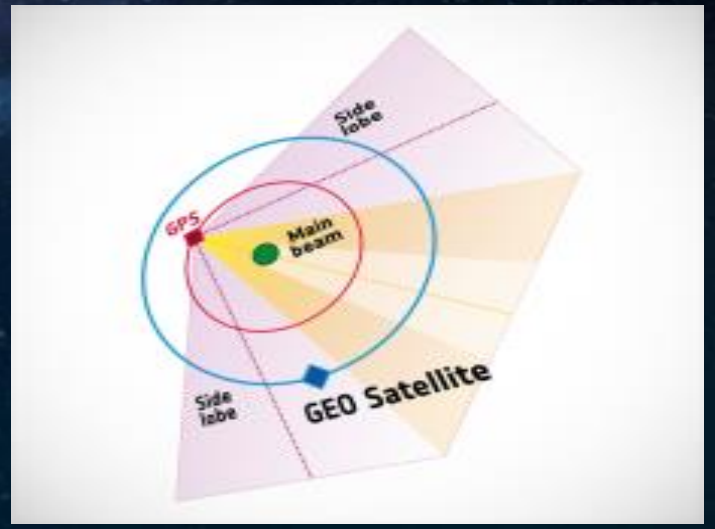
Arthur C Clarke's 1945 Paper

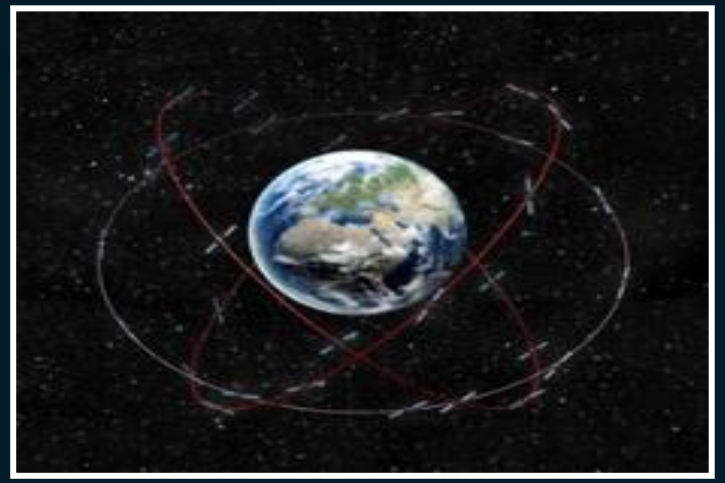
European Data Relay Satellite

GNSS monitoring from GEO

- The concept is to monitor all GNSS satellite transmissions using two or more GEO satellites

- Possible applications include:-
  - GNSS integrity monitoring
  - Meteorological measurements
  - Earthquake forecasting
  - Jammer detection and geolocation
  - High precision orbit determination
  - Orbital drag estimates
  - GNSS reflectometry
  - GNSS imaging
  - Investigation of scintillation



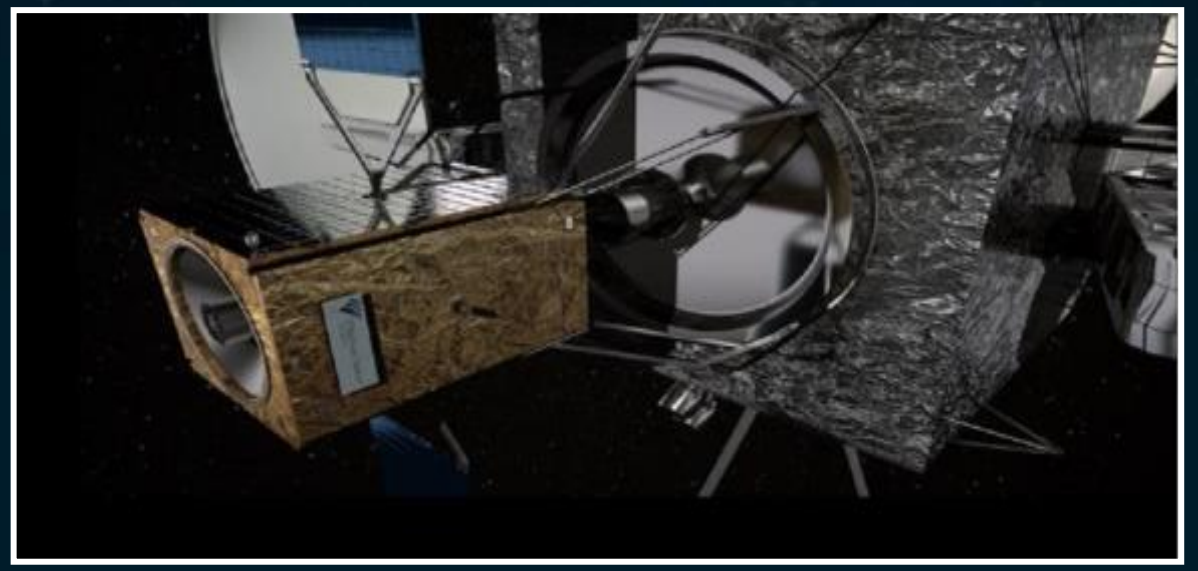


GEO Satellite Clusters

- Clusters of smaller GEO satellites offer resilience, flexibility, increased capacity over specific theatres, and novel capabilities such as interferometric communication beams

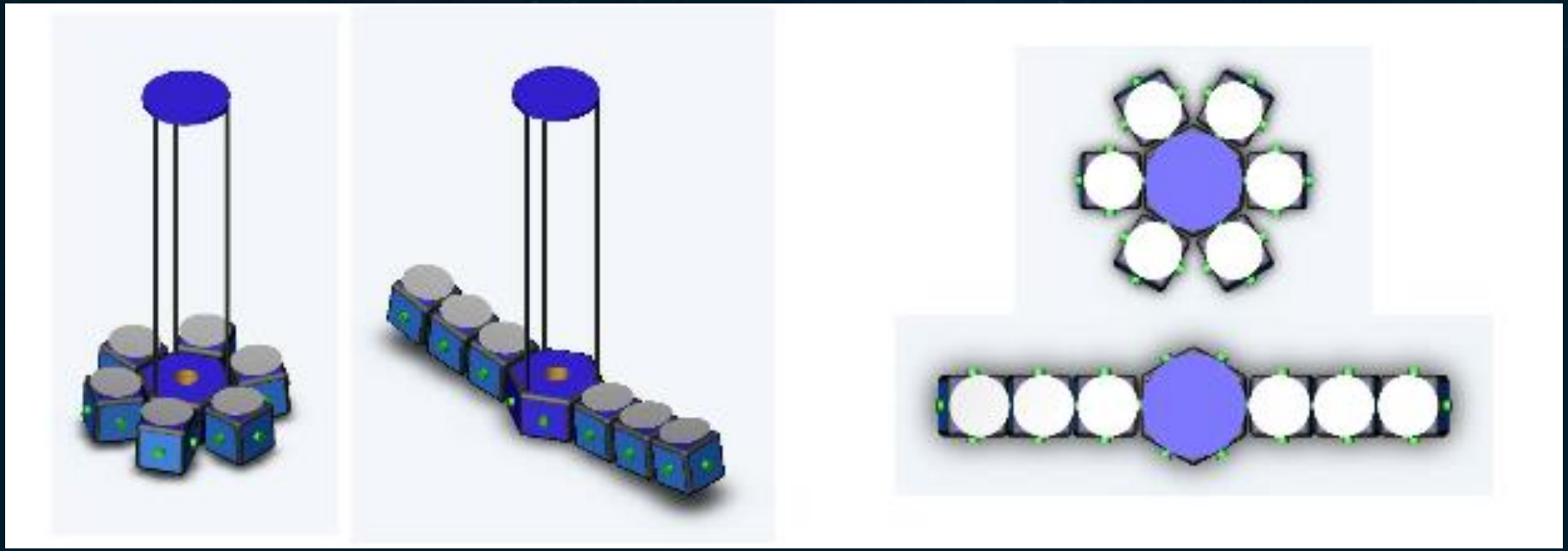
Satellite Servicing Concepts

- A number of organisations are currently working on satellite servicing concepts
- Launched alongside a future GEO satellite, these could offer a variety of different mission options
- Reliance solely on on-board sensors entails risk – precision SSA can help



Satellite Assembly On-Orbit

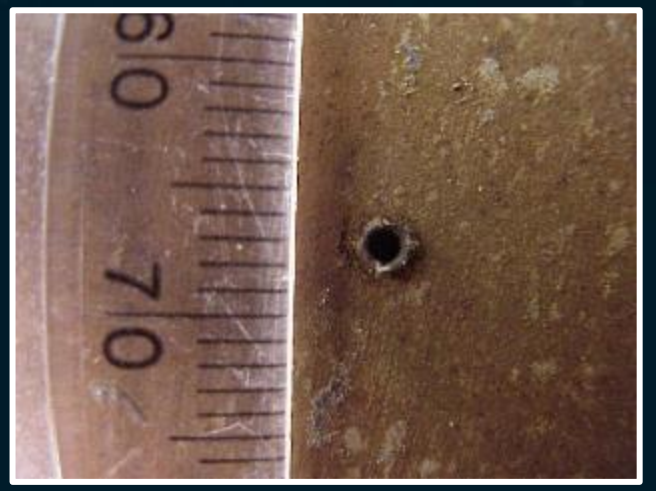
- Future surveillance concepts such as SSC's Aarest could involve reconfigurable sub-apertures to build larger mirrors in space
- Precision SSA will enable accurate rendezvous



Debris Population Characterisation

- The potential exists to use debris objects as “witness plates” to characterise the un-tracked small debris population

- Frequent, high accuracy tracking of objects in LEO would allow perturbations caused by impacts to be identified



Debris Removal

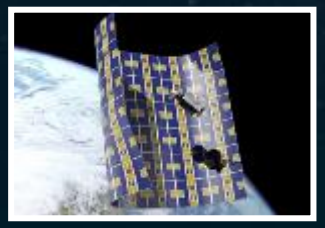
- A variety of technologies, including Mass drivers; Adhesives; Harpoons; Lasers; Tethers; Nets; Grapplers; Propulsion plumes; Slingsats; Branes; De-orbit sails; and Electrostatic tractors have been suggested to remove large, long-lived debris objects
- All these concepts are technically immature and look like anti-satellite weapons in the wrong hands. It's unclear how these concepts would be financed, and the politics is hard too

Mass driver concept

Harpoon concept

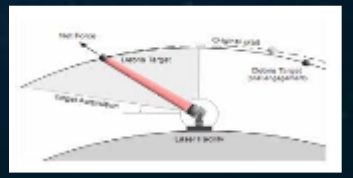
Propulsion plume concept

Adhesive concept

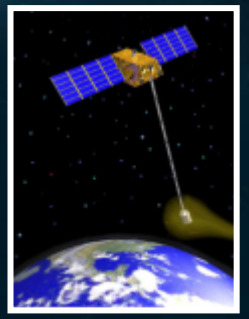


Brane concept

Electrostatic tractor concept



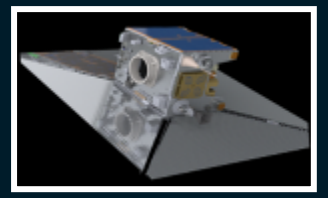
Laser concept



Tether concept

Slingsat concept

Net concept



De-orbit sail concept

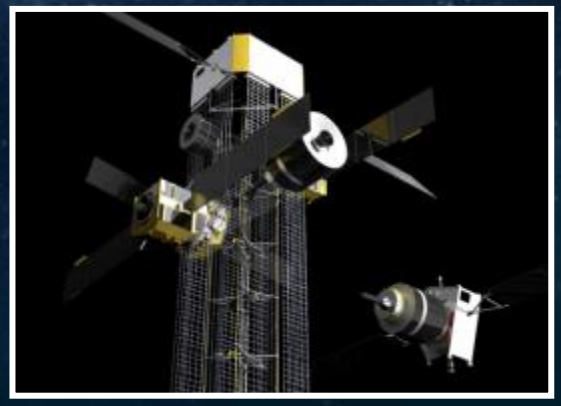
Grappler concept

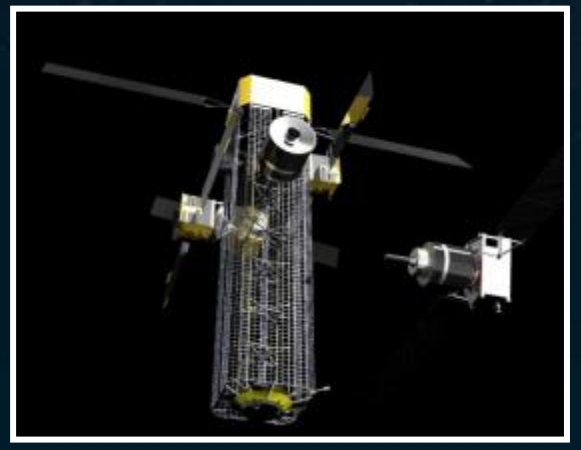
Transparent, precision SSA will be needed on target objects

Necropolis Concept

- **Technical Requirements:**
  - Trackable and manoeuvrable
  - Serviceable – the Necropolis will need fuel
  - Able to manage charging
  - Able to passivate satellites delivered to it
  - Able to process materials delivered to it

Satellite Disposal Facility in Orbit





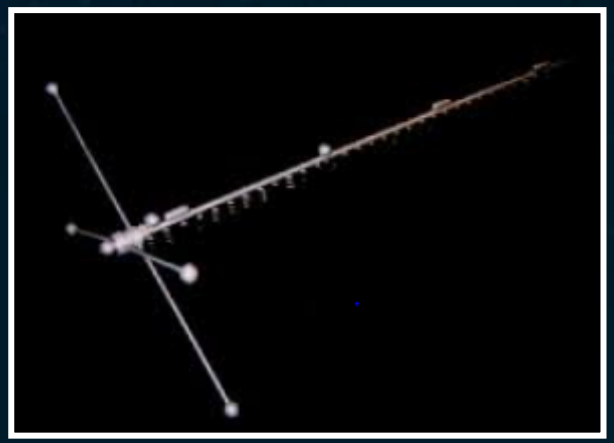
- **Benefits:**
  - Significantly less satellite de-orbit propellant
    - Lighter constellations – fewer rockets required
  - Less risky constellation disposal
  - Potential for refuelling subsequent missions using recycled materials
    - Metals and/or carbon

Precision SSA is again an enabler

Space Debris As Fuel

- Supposing that we could use space debris as a propellant……..
- A team in Australia is developing a thruster that works by ionising metals (and carbon) and accelerating them
- Mass-drivers have also been suggested, which can utilise almost any type of debris
- Space debris then becomes an on-orbit resource
- Precision SSA data on the location of suitable pieces of debris suddenly increases in value

Electric propulsion concept



Mass-driver concept

Conclusions

- Precision SSA offers the potential for a number of novel space-based applications, and enhances some existing ones
- It will help to maintain the confidence of both investors in satellites and the space insurance industry that sustainability is being taken seriously
- With improved SSA and Space Traffic Control, the space industry stays in business!

The scene from the movie Wall-E that we need to avoid***!***

Is there an up-side to space debris?

Thanks

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