GNOSIS Precision SSA Workshop

UK SSA Needs and drivers for GNOSIS

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Dstl Introduction

- Executive Agency of Ministry of Defence (MOD) delivering S&T

- ~50% of work is externally delivered
  - Working with academia and industry essential
  - For SSA have the Astrodynamics Community of Interest (ACI)

- 4,500 people
  - Mix of permanent and non-permanent staff
  - Scientists, military advisers, strategic partners and support staff

Delivering high-impact S&T for the UK's defence, security and prosperity

- Uplifted £50M Space Programme initiated in April 2017

SSA – UK Top-level Drivers

- Articulated in 2014 National Space and Security Policy (NSSP)

- Reinforced in 2015 Strategic Defence and Security Review (SDSR)

- Develop UK Space Operations Centre (UK SpOC) at High Wycombe

- Recognised critical nature of Space-derived capabilities

- Changing environment → debris, new mission concepts, economics

Key Dstl SSA Activities

- Develop UK astrodynamics capability
  - Novel sensor solutions
  - Test/develop processing and collection techniques/algorithms
  - Data & sensor fusion
- Conduct SSA experimentation
  - International and UK supplier engagement
- Research into future space challenges
- Astrodynamics Community of Interest (ACI)
- International Research Collaboration (IRC)

Equipment testing at Dstl Porton Down

Why the need for enhanced SSA?

- Legacy processes not well suited to today's challenges
  - Original development driven by Missile Warning needs at start of space age
  - Recognising missiles from satellites rapidly key factor in design
  - Timeliness critical for survivability
  - Surveillance of Space as an enabler
  - Drove development of technical solutions with technology available at the time; hence SGP-4 & TLEs

- SSA key enabler for UK access to space & space services
  - Now living in a Contested, Congested, Competitive space domain
  - SSA provides foundational capability to civilian and military users

- Quantify risk to space-capabilities & ensure continued access
  - PNT (GPS/ Galileo), SATCOM, Space tourism, launch, ISR etc.

- International interest growing, need allied solutions

UK SSA Needs
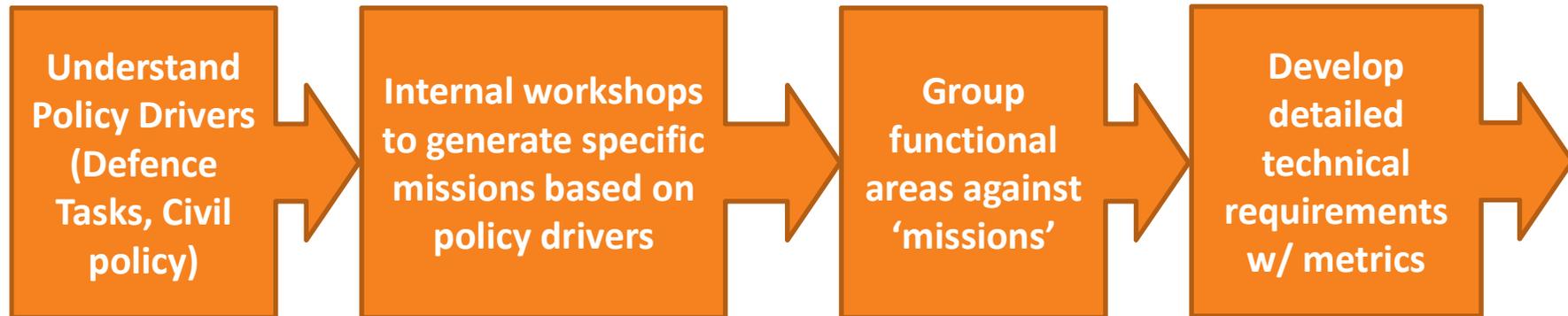
Background

- Definition of formal SSA requirements is difficult:
  - Need to define a whole architecture solution
    - Can't just think 'processing' separate from 'sensors'
    - One can be traded with the other (c.f. Dstl-DSTG LEO experimentation)
  - Metrics are tricky!
    - What is the 'value' of my SSA datum/ data?
      - May vary as a function of time, priority, age, object, quality…
      - Enumeration of hard and soft factors required
  - **Lots** of stakeholders
    - Civilian and military needs at a technical level may look similar
    - Coordination of programme/ funding needed
- Dstl work conducted to help inform HMG requirements

Methodology

Understand Policy Drivers (Defence Tasks, Civil policy) → Internal workshops to generate specific missions based on policy drivers → Group functional areas against 'missions' → Develop detailed technical requirements w/ metrics →

Candidate Missions examined

- Satellite Warning Service (SWS)

- Force protection of HMG GEO assets (e.g. SATCOM)

- Force protection of HMG LEO assets (e.g. ISR)

- Force Protection for HMG MEO assets (e.g. GNSS)

- Satellite de-confliction with terrestrial activity (laser use, launch etc.)

- UK license compliance monitoring

- Compliance of other nations to international policy

- Conjunction assessment to UK owned/ licensed satellites

- Liability assessment including fragmentation analysis

- Re-entry warning for UK licensed satellites

- Re-entry warning for all satellites liable to re-enter over UK territory

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Resultant UK Needs – Comments

- Clearest needs include SWS, re-entry warning and license compliance monitoring based on national need or international obligations (notably UN treaties)

- This drive SSA needs in all orbital regimes (LEO to GEO and graveyard)

- Some implied needs:

  – Understand the composition and status of active satellites; notably those owned/ licensed by UK and those of high interest to MOD (e.g. Earth Observation, SATCOM, PNT)

  - At a minimum want to retain continued custody of these, e.g. to enable re-acquisition over time periods ~days

  - Want some form of basic characterisation for most missions, for instance activity such as size, manoeuvre, stability on orbit etc.

Resultant UK Needs – Comments

- Most stressing requirements surround Conjunction Assessment:
  - Expect that at a minimum we want CA to cover >10cm population; with an aspiration of >2cm objects that can pose a risk to UK assets
    - Again want to retain continued custody of these, e.g. to enable re-acquisition over time periods ~days; here dynamics of the smaller debris and detectability require further consideration (e.g. SRP/ drag effects)
    - Growing recognition of need to better understand small/ faint but high area to mass (HAMR) objects around GEO, not currently routinely catalogued, that could affect SATCOM
      - Driver for collaborative Dstl-University of Warwick observation campaigns with INT

Relationship to Precision SSA

- Trade-off possible between sensors/ data and processing
    - UK contributes sensor data to allied networks (e.g. CSPO) to obtain access to much large pool of assets
    - Also considering what can also be done independently
- Precision OD becomes vital when have only small* number of sensors to work with…
    - "small" scales based on mission and architecture (sensors : objects ratio)
    - But also considering challenge associated with dynamics
        - Manoeuvre, especially when not easy to predict (EP)
        - Orbital regimes outside normal LEO, GEO paradigm, notably HEO and GTO but also deliberate NKO

Future Space Challenges

Context

- A key element of Dstl work is to understand future space challenges, i.e. changing nature of space usage
  - Daedalus de-orbit sail experiment 2017 – 2019
    - Explored impact of increased drag due to sail deployment on LEO SSA sensors
  - Horizon scanning and SSA implications study (2018-2019)
    - Analysed space technology and mission trends
    - Reported at AMOS2019
  - GEO RPO campaign; PHANTOM ECHOES I & II

2018 Horizon Scanning Activity

Non-Traditional Orbits and Dynamics

- Increasing Use of Non-Keplerian Orbits*
- Usage of Novel Orbit Regimes
- Variable (e.g. Spiral) Trajectory Dynamics*

Novel Spacecraft Compositions

- Non-traditional or Variable Form Factors
- Non-traditional Spacecraft Materials
- Standardised/Mass-Produced Platforms

- Improvements in Orbit Transfer & Control
- Proliferation of Small, Manoeuvrable Spacecraft*
- Increased Flight Autonomy
- Novel Mission/Life Cycles
- Signature Control (enhancement/reduction)

Vehicles Operating in Proximity

- Proliferation of Tethered Objects
- Routine Rendezvous Missions*
- Proliferation of Free-Flyer/Formation Missions*
- Increased Sub-Object Deployment

Enhanced Spacecraft Operations and Behaviour

PHANTOM ECHOES

Simon George (Dstl) – 5-eyes Lead and UK Lead

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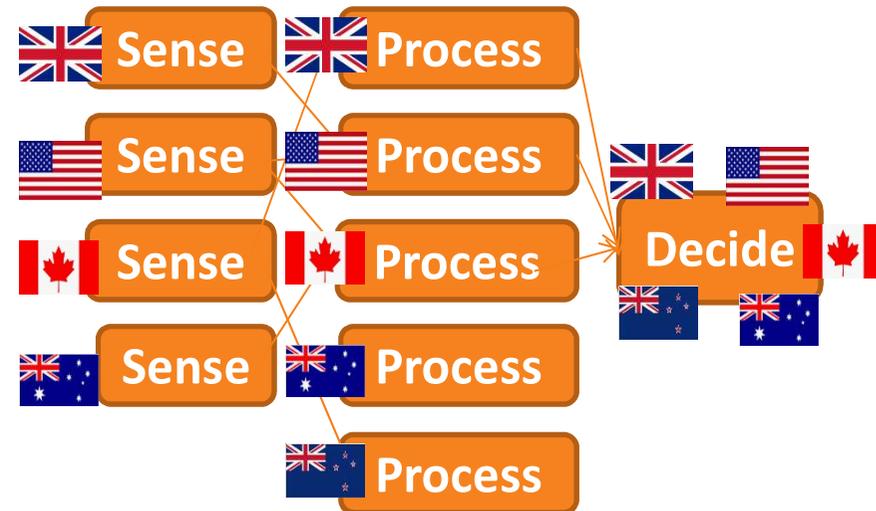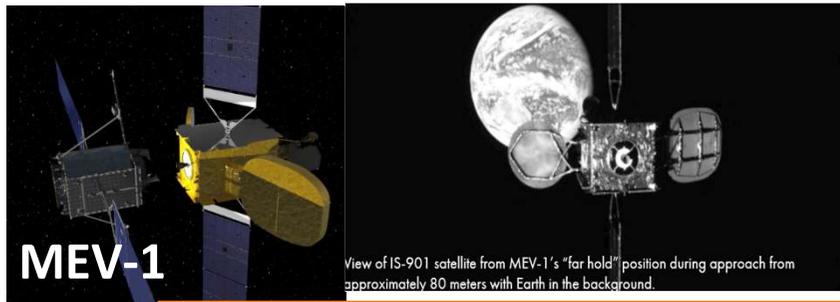
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Phantom Echoes

A cooperative 5-eyes SSA experiment to enhance coalition capability by leveraging national systems

Demonstrate astrodynamics tools to enhance awareness of on-orbit activity

→ Inform CSPO/ National programmes

→ Develop SSA requirements

MEV-1

View of IS-901 satellite from MEV-1's "far hold" position during approach from approximately 80 meters with Earth in the background.

Sense	Process
Sense	Process
Sense	Process	Decide
Sense	Process
	Process

Next phase: MEV-2 due to launch this month and execute on-station servicing over Atlantic

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Astrodynamic Challenges

- MEV-1's initial orbit-raising geometry (12000 x 65000 km) presented natural tracking challenges:

  » (5-7) day gaps in coverage from a single site: uninterrupted custody requires a global sensor network

  » Geometry maximises time in the Sun (for electricity generation), minimising time in eclipse: reduced opportunities to observe, limited time/resource at night to "search" and reacquire, etc.

- Constant-thrust orbits (e.g. electric propulsion orbit-raising) cannot be suitably represented by a TLE – these are only sufficient for a coarse track for a limited period of time

 » Effectively non-Keplerian; varying thrust magnitude & geometry

Astrodynamic Challenges

- Available orbital information often not of sufficient latency or cadence to acquire constant-thrust objects with narrow-field sensors:
  - » Inability to rely on solely (public) TLEs for sensor acquisition & cueing on constant-thrust objects
  - » Catalogue maintenance can be a challenge: significant sensor resource required to maintain full custody

- Steering & cueing of sensors based on purely TLE/Keplerian inputs remains problematic
  - » Some manual cueing success using rough metrics and/or predictive cueing techniques
  - » Value in using small/coarse sensors to cue larger, more precise systems

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Astrodynamic Challenges

- Orbit Determination solutions challenging with sparse observations:
    - » Requires dense tracks in order to improve success of (e.g.) OD, manoeuvre processing, estimation of thrust forces
    - » Once "lost", reacquisition requires wide-field 'survey' sensors augmented by track association and/or satellite identification capability

- Some success in (manual) re-acquisition success using rough metrics and/or predictive cueing techniques:
    - » However, no fixed hand-off/cueing format or mechanism to "tip" other sensors
    - » Currently a mix of message notations, e.g. modified TLEs/ELSETs, (pseudo-) time offset information, etc.

PHANTOM ECHOES 2
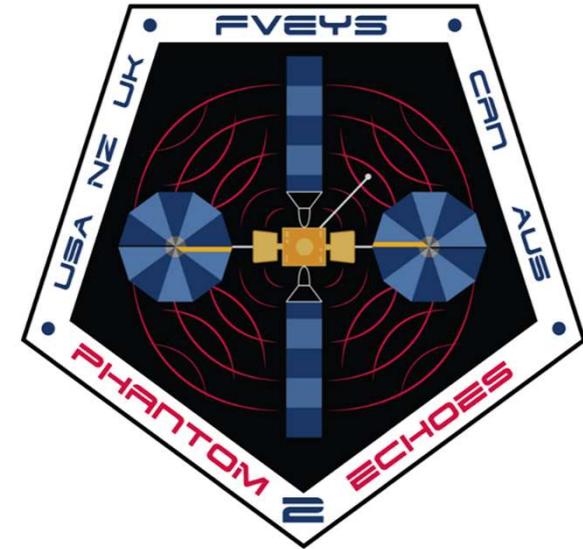
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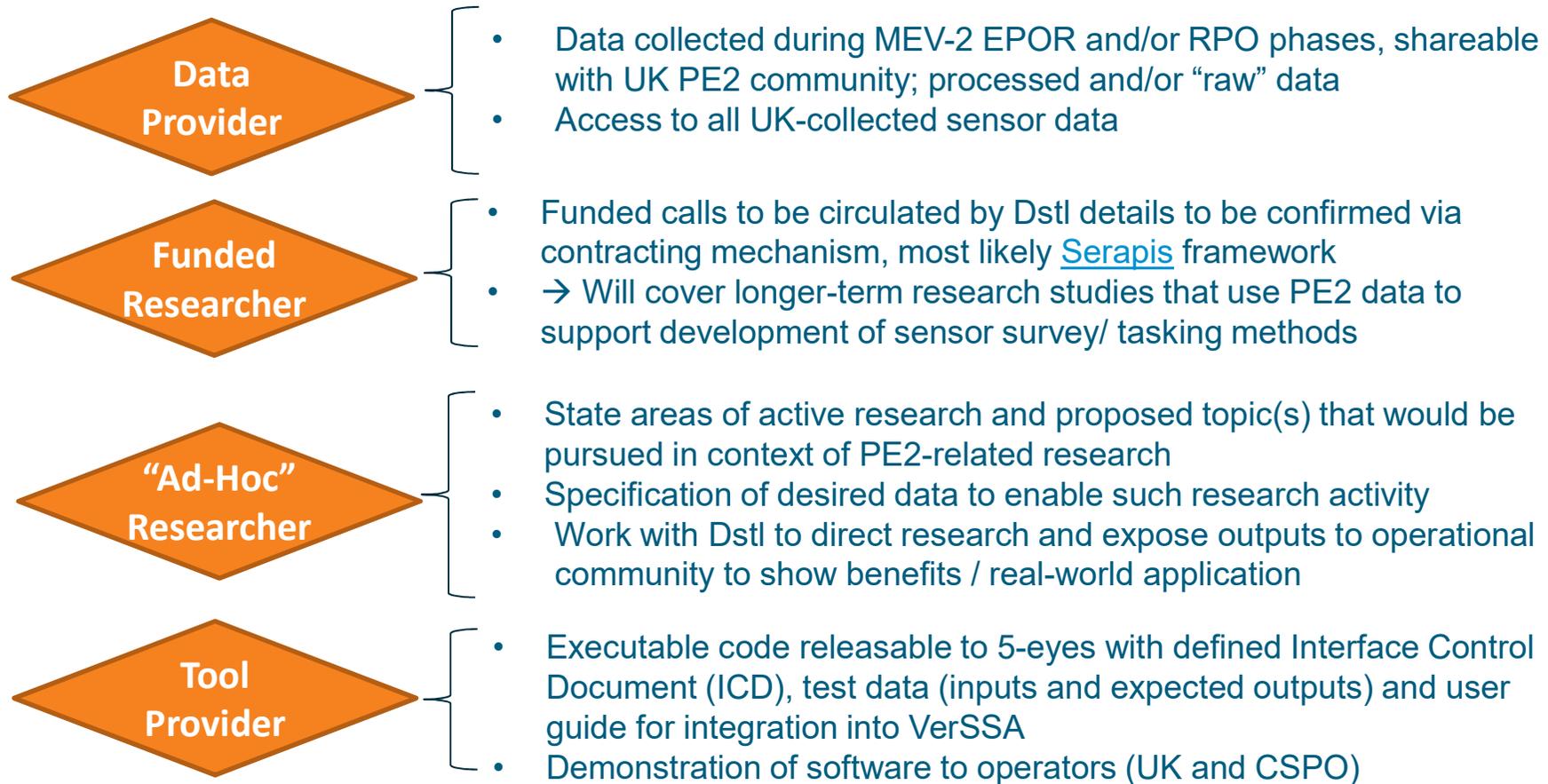
Planned custody experiment

➤ **Can the PE community observe and maintain custody of *MEV-2* during EPOR, without using externally provide cues?**

    ➤ Generate indigenous "TLEs": use to generate indigenous orbit cues to re-acquire, update and maintain custody during 2-week period

- Global distribution of observing sites desirable

- Explore collective data repository & automated state-update processes

- Develop tip-and-cue methodology for reacquisition and handover

- CHALLENGES:

- Can we accurately "forecast" *MEV-2*'s position 2 days in advance?

- Are there improved ways to hand-off orbit cues to other sensors?

- Can we "find" MEV-2 again, if it is 'lost'?

Routes to involvement

Data Provider
- Data collected during MEV-2 EPOR and/or RPO phases, shareable with UK PE2 community; processed and/or "raw" data
- Access to all UK-collected sensor data

Funded Researcher
- Funded calls to be circulated by Dstl details to be confirmed via contracting mechanism, most likely Serapis framework
- → Will cover longer-term research studies that use PE2 data to support development of sensor survey/ tasking methods

"Ad-Hoc" Researcher
- State areas of active research and proposed topic(s) that would be pursued in context of PE2-related research
- Specification of desired data to enable such research activity
- Work with Dstl to direct research and expose outputs to operational community to show benefits / real-world application

Tool Provider
- Executable code releasable to 5-eyes with defined Interface Control Document (ICD), test data (inputs and expected outputs) and user guide for integration into VerSSA
- Demonstration of software to operators (UK and CSPO)

Summary

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Summary

- UK need for SSA increasing, a fact recognised at senior levels

- Dstl supporting HMG in defining requirements as informed by future space challenges and technical feasibility

- Precision SSA essential to support custody of manoeuvrable targets especially when in challenging orbits (e.g. GTO)

- Keen to support the work of GNOSIS
    - Help define problems
    - Provide data from experiments
    - Identify use cases/ exploitation routes
    - Support to academia e.g. iCASE awards