amazon | project kuiper

Operator CDM Response Coordination

SSA Operators Workshop, June 3 2022

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Our Mission

Project Kuiper is an initiative to increase global broadband access through a constellation of satellites in low Earth orbit (LEO). Its mission is to deliver fast, affordable broadband to unserved and underserved communities around the world.

Space safety and sustainability

Space safety and sustainability is a core tenet for the Kuiper team, and we are committed to taking all the necessary steps to protect against orbital debris and prevent conjunction events.

Constellation design

- 20 km altitude separation between shells
- In-track separation of at least 50 km
- No more than 9 km of cumulative altitude deviation

Reliability

- Comprehensive subsystem and system testing, in the factory and on orbit below ISS prior to orbit raising
- Ephemeris and maneuver plan sharing

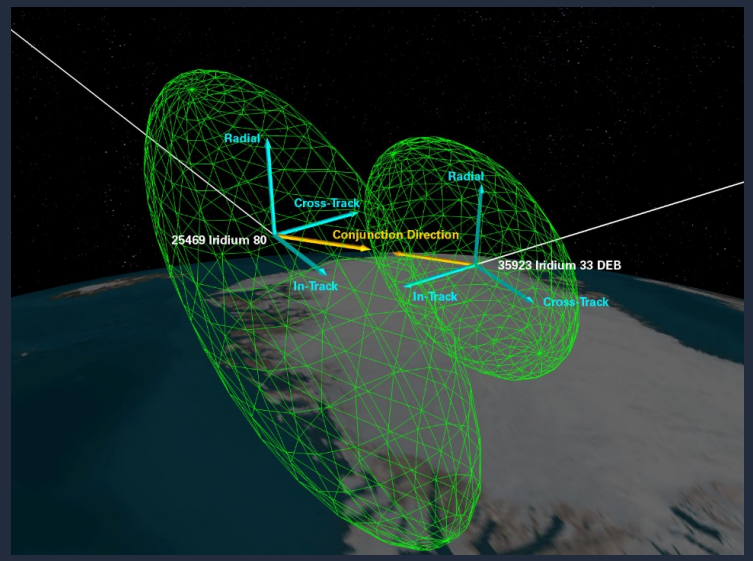
Deorbit and demise

- Active deorbit in most cases within one year
- Passive deorbit not expected to exceed 10 years based on natural decay due to atmospheric drag



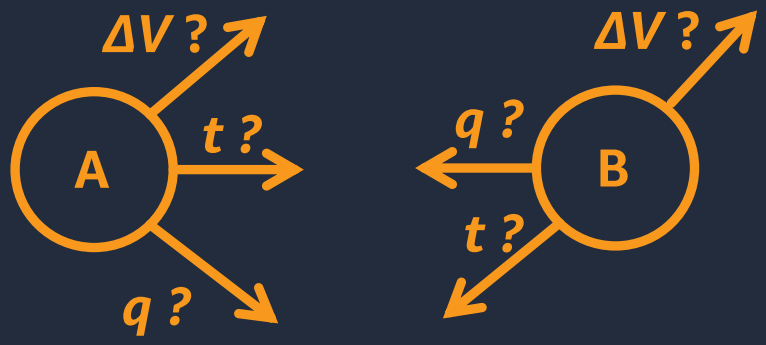
Challenges of Satellite CDM Response

State Uncertainty

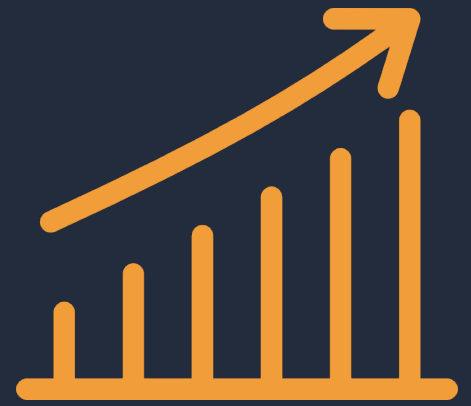


Credit: Hall et al.

Action Uncertainty



Scalability



Hall, Robert, Sal Alfano, and Alan Ocampo. "Advances in satellite conjunction analysis." Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference. 2010.

Addressing CDM Response Challenges

Understanding



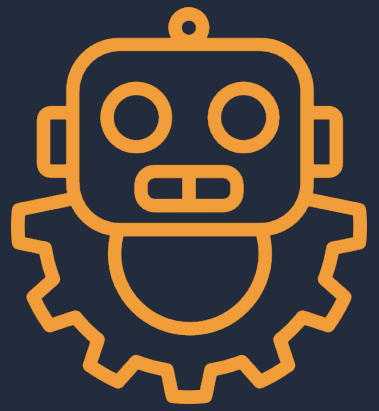
- Accurate dynamics models for state and covariance propagation
- Modeling and representation of conjunction event risk
- Increasing quality, frequency, and accessibility of SSA data

Coordination



- Exchange of data necessary for decision making including ephemeris and maneuver plans
- Determining who will respond, how they will, and when actions will occur

Standardization & Automation



- Pre-coordination of conjunction event response
- Standardization of data exchange formats, system modeling, and communications

Conjunction Event Response Spectrum

Human-Driven

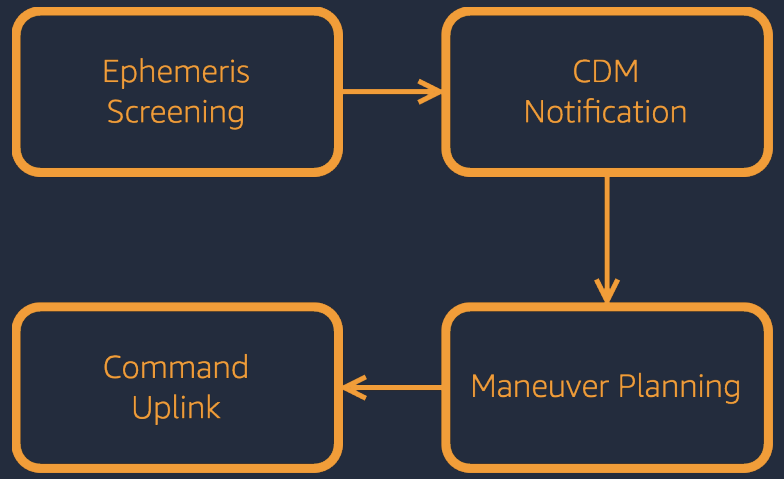


Credit: ESA

- Can more easily adapt to new and evolving scenarios
- Does not require pre-coordination of response plan

- Scales with conjunction events by adding more people
- Susceptible to human factors failures of complacency, pressure, and lack of communication

Automation-Driven



- Scales with conjunction events by adding more compute
- Removes human-errors from conjunction event response

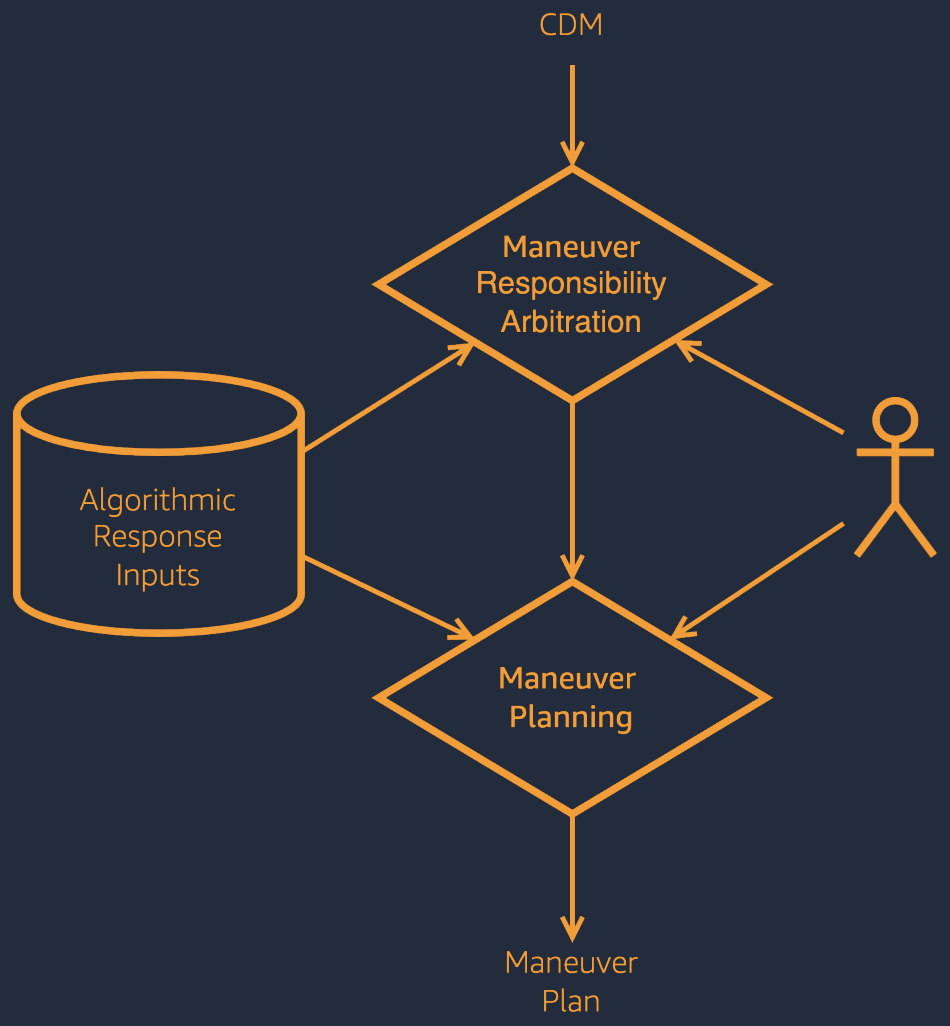
- Requires pre-coordinated and verification response plans
- Validation and verification requirements make adaptation to new situations challenging

Algorithmic Conjunction Event Response

Goal: Establish rule-based logic to safely respond to the most commonly occurring satellite vs. satellite conjunction events

Possible Inputs:

- Operator
- Crewed Vehicle
- Satellite IDs
- Mission Phase (Ascent, Station Keeping, Deorbit)
- Maximum Tolerated Probability of Collision
- Maneuver Timeline
- Satellite Maneuverability Status
- Elapsed Mission Duration
- Rule Validity Period
- Satellite Ephemeris
- Satellite Maneuver Plans
- Satellite Propellant Reserves



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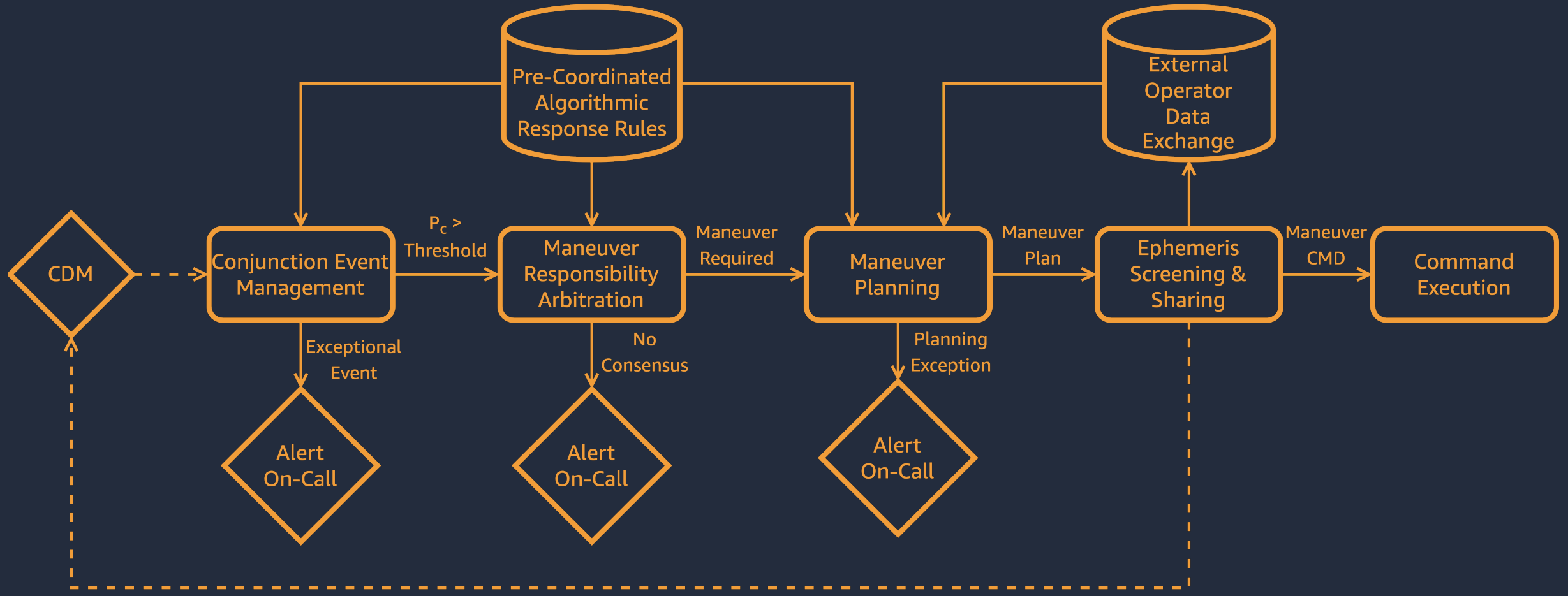
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Mission Phase		Sat 2		
		Ascent	Station Keeping	Deorbit
Sat 1	Ascent	Sat 1	Sat 1	Sat 2
	Station Keeping	Sat 2	Sat 1	Sat 2
	Deorbit	Sat 1	Sat 1	Sat 1

Hypothetical Decision Table
For Maneuver Responsibility Arbitration

Algorithmic Conjunction Event Response





Prototype Missions

Amazon will launch two prototype satellites – KuiperSat-1 and KuiperSat-2 – by Q4 2022.

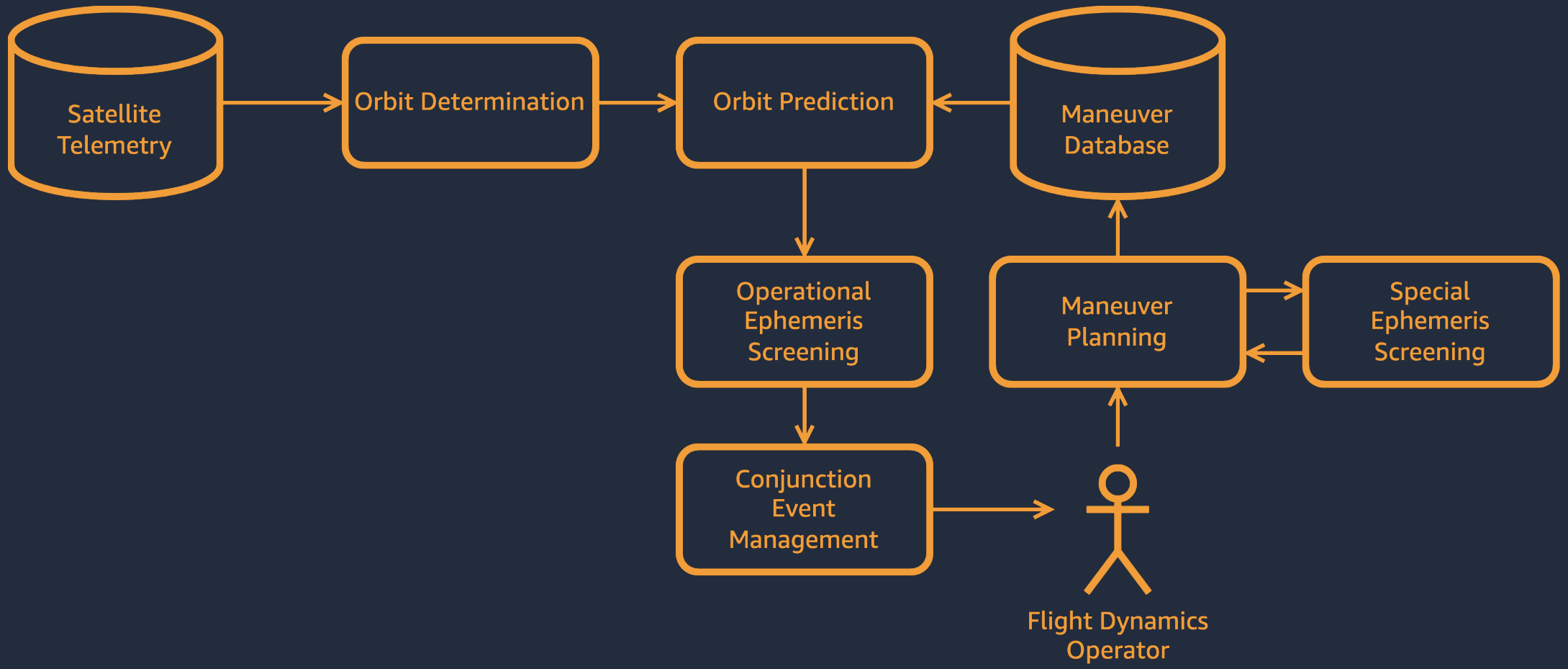
Mission Objectives

- Missions will allow us to test communications and networking technology used in our final satellite design, and validate launch and mission management procedures.
- Prototypes include production-ready technology and sub-systems, including phased array and parabolic antennas, power and propulsion systems, and custom-designed modems.

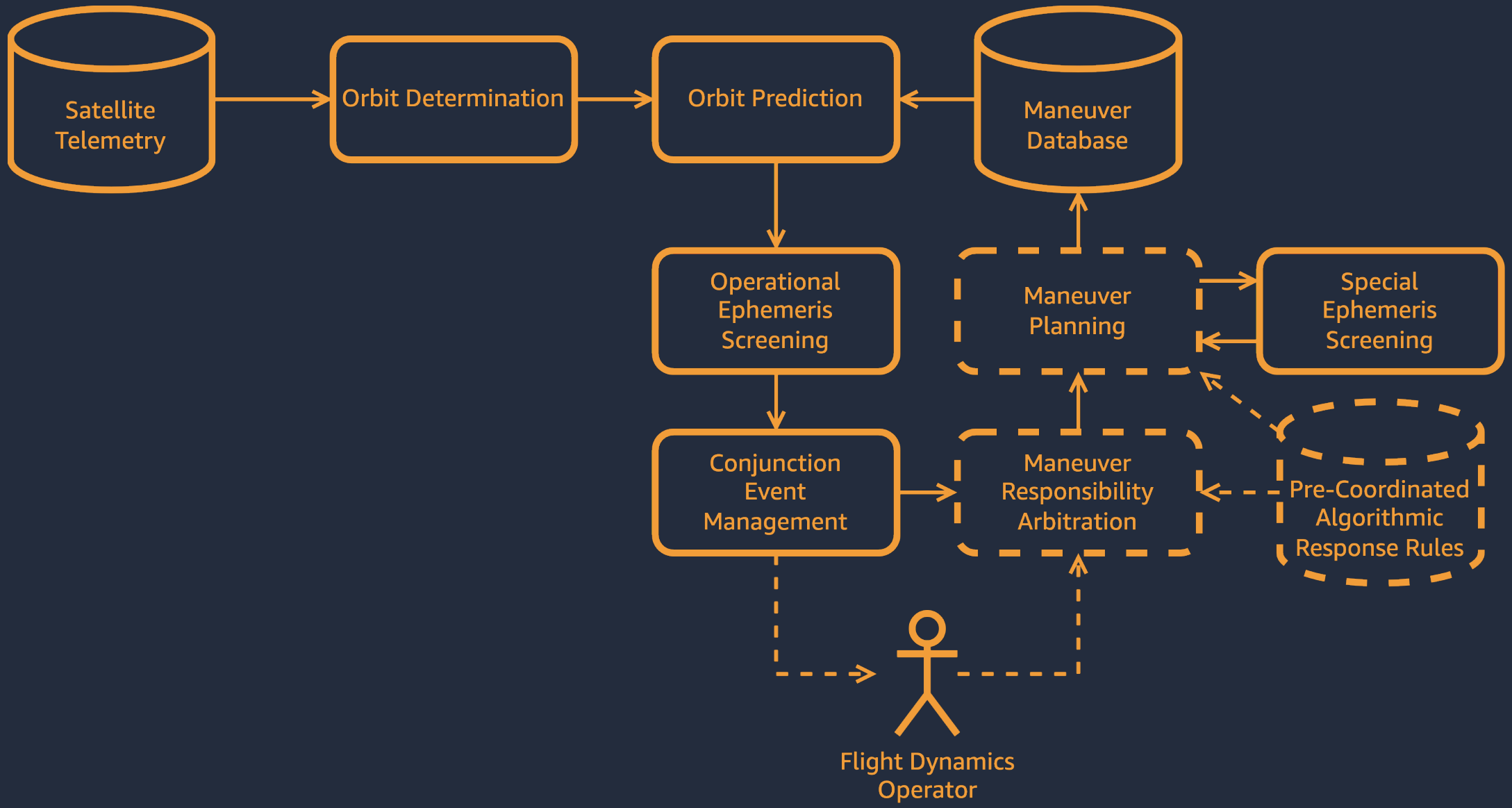
Kuiper Space Operations Objectives

- Direct on-orbit validation of flight dynamics algorithms for astrodynamics and maneuver planning
- Demonstrate core software services for orbit determination, prediction, risk assessment, and ephemeris screening
- Validate ephemeris sharing and CDM alerting with independent human monitoring and oversight
- Actively deorbit satellites at end of mission

Kuiper Prototype Space Operations



Incremental Algorithmic Response Adoption



Thank you

Questions, Coordination?

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Constellation Management & Space Safety

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Key Safety Engineering Principles

- Design Specification
- Implementation Transparency
- Formal Verification
- Performance and Robustness
- Run-Time Monitoring

Algorithmic Conjunction Event Response

Example Event Sequence

1. Receipt of CDM from common SSA Provider
2. Rule Evaluation
3. Result Generation
4. Exchange and confirmation of Outcomes
5. Execution of action

Mission Phase		Sat 2		
		Ascent	Station Keeping	Deorbit
Sat 1	Ascent	Sat 1	Sat 1	Sat 2
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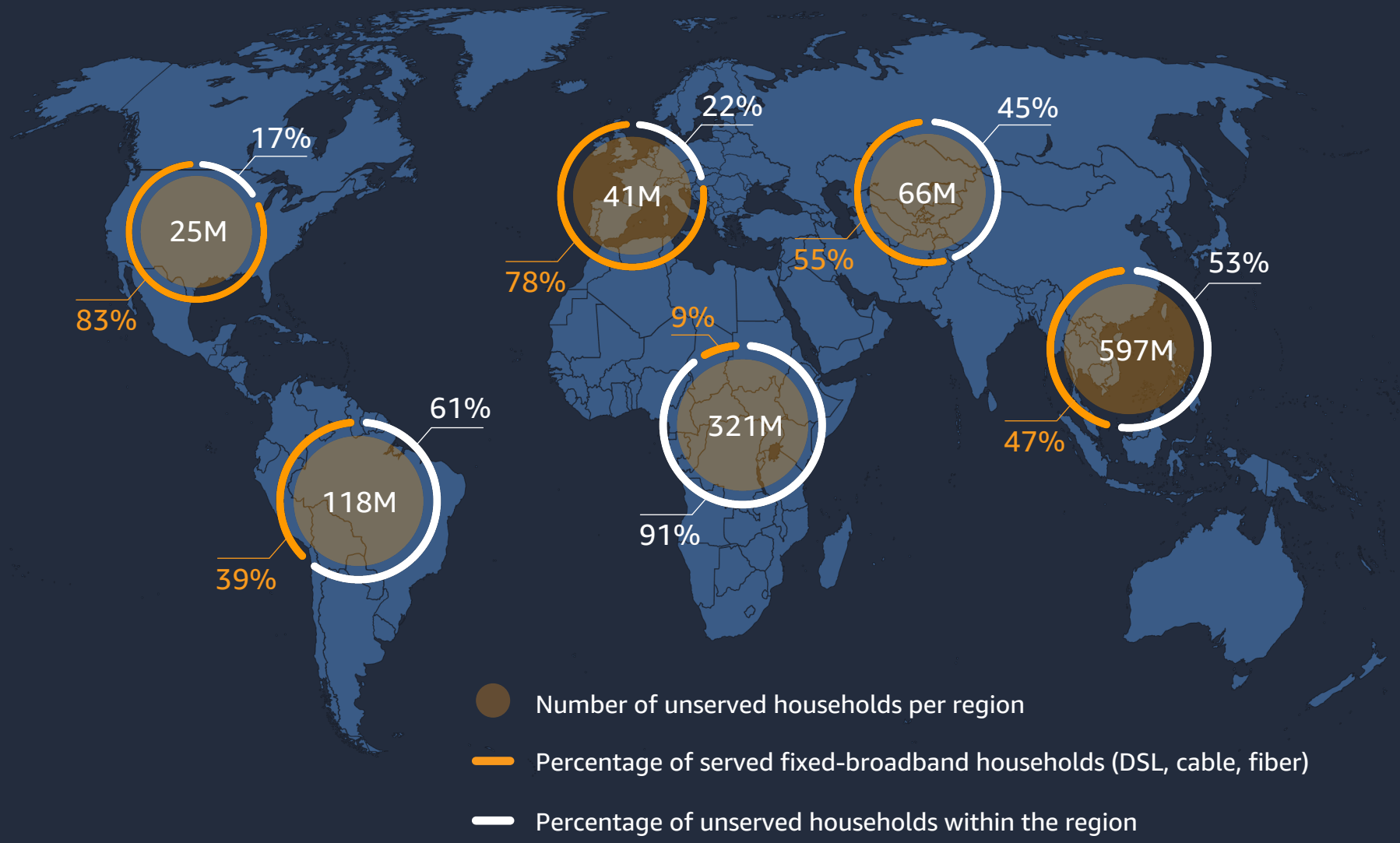
Bridging the digital divide

There are billions of people on Earth without reliable broadband. Project Kuiper will bridge the gap in places where service is unreliable or expensive, or where it doesn't exist at all.

1 billion
unserved households across the globe have no fixed broadband today (50% of the global total).

300 million
underserved households are on legacy DSL technologies.

100 million
business, enterprise, and public sector endpoints lack reliable connectivity.



Source: S&P Market Intelligence

Amazon Confidential

Our guiding principles



Customer-First
We start with the customer and work backwards. Our services are designed to delight customers, and to provide a simple, convenient experience every step of the way.



Affordability
Amazon has a long-standing commitment to low prices. We are inventing new technologies to ensure Project Kuiper is affordable and accessible for our customers.



Reliability
Customers around the world trust Amazon to provide reliable service, from same-day delivery to cloud solutions. Project Kuiper will deliver the same reliable, consistent service for our customers.



Safety
We are committed to operating safely across every aspect of the Kuiper System, from our orbits in space to our facilities here on Earth.



Security
We will always protect the security and privacy of our customers, from individual households to large enterprise and government customers.



Sustainability
Amazon is committed to building a sustainable business for our customers and the planet, and we are inventing new ways to protect the space around Earth.

Amazon Confidential



Prototype Missions

Amazon will launch two prototype satellites – KuiperSat-1 and KuiperSat-2 – by Q4 2022.

Mission Objectives

- Demonstrate core software services for orbit determination, orbit prediction, and risk assessment
- Demonstrate and validate core flight dynamics algorithms algorithms for maneuver planning and guidance
- Demonstrate ephemeris sharing and screening with SpaceTrack and the 18th SPDS

Safety & Sustainability

- Prototypes are designed for atmospheric demise and will be actively deorbited after the mission completed.
- One of two satellites will include a sunshade to evaluate ways to mitigate impact on optical astronomy.