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THE FRENCH AEROSPACE LAB

Autonomous Agents and Multiagent Systems Challenges in Earth Observation Satellite Constellations

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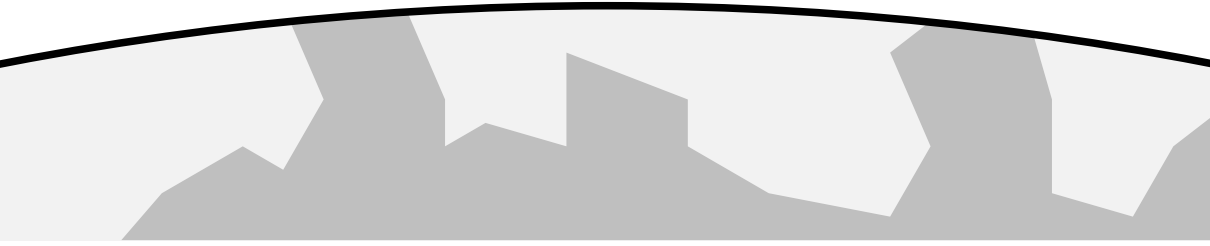
Many open challenges for autonomous agents and multiagent systems

Constellation Design Challenges

How to Design an EOS Constellation?



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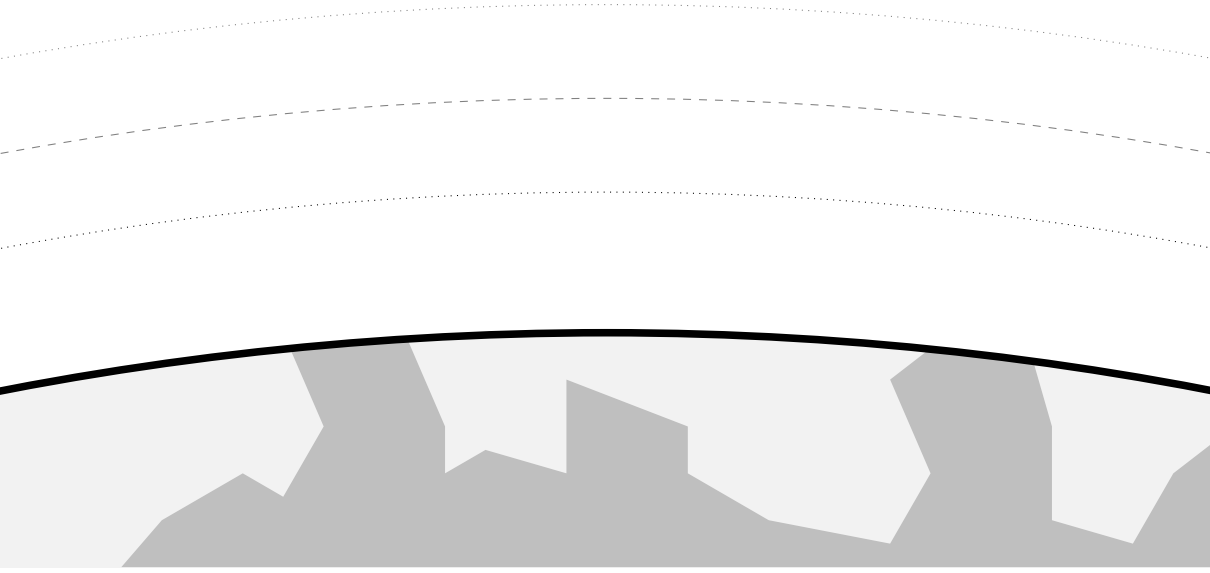

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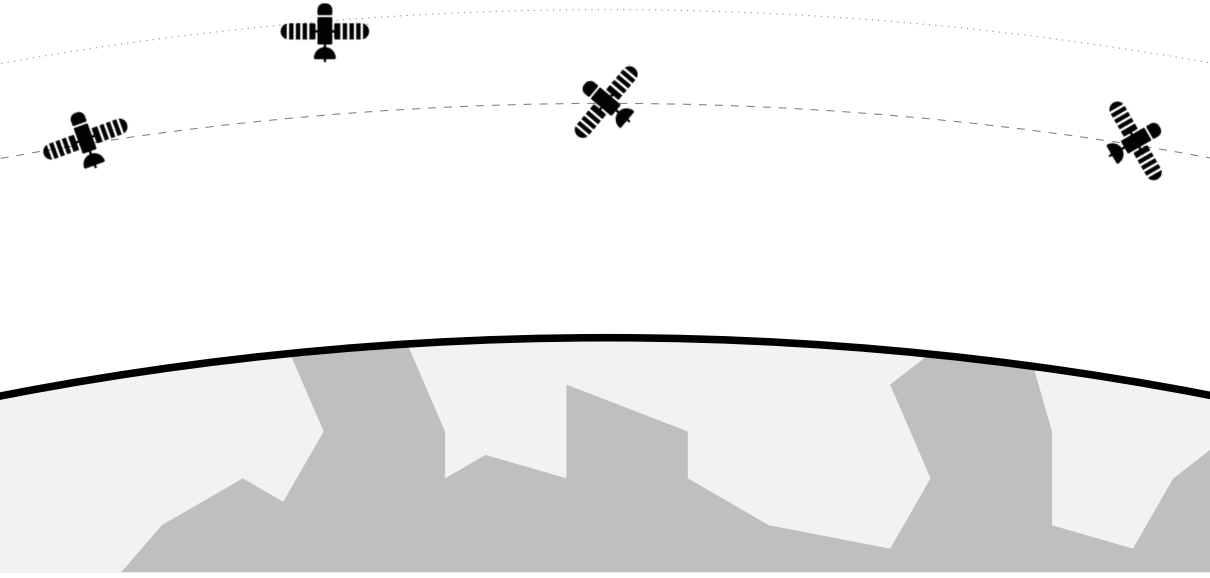

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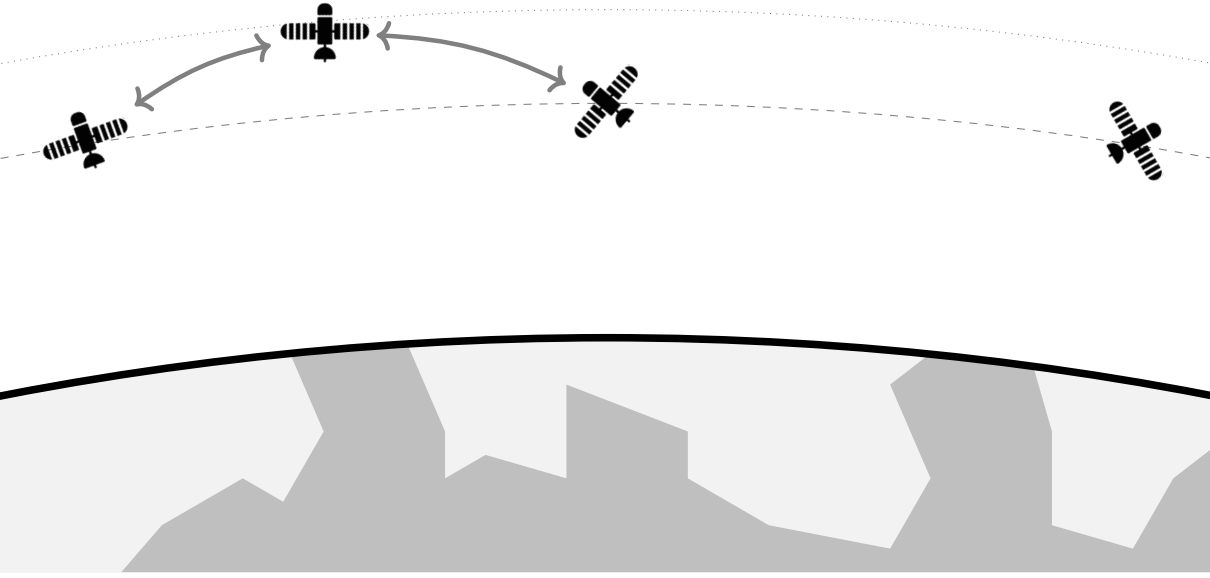

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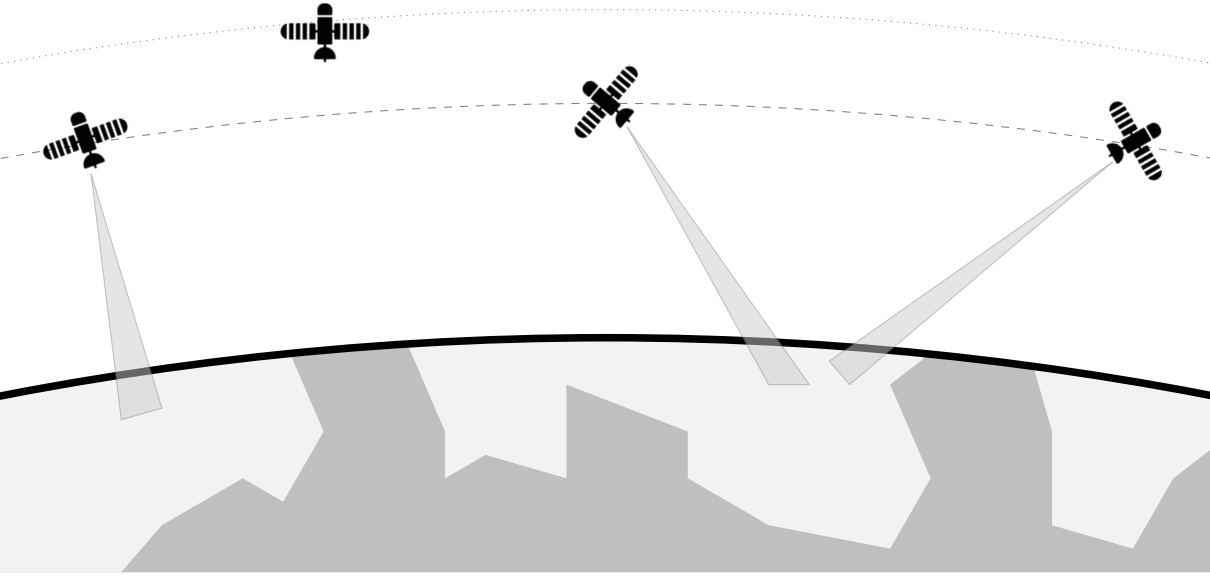
Points of interest



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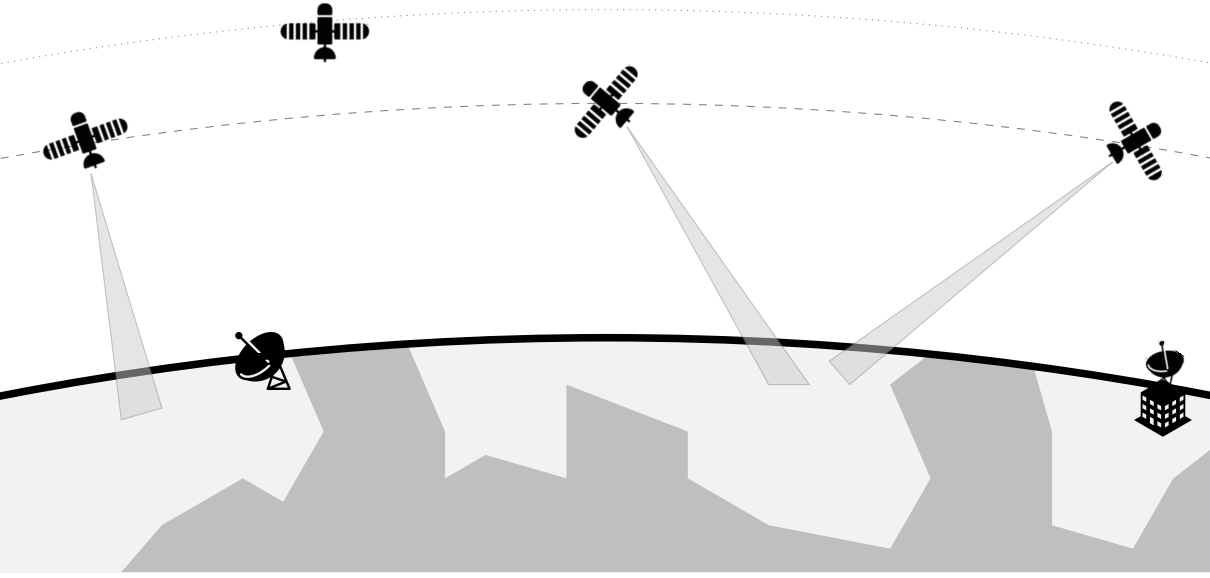
On-ground communication stations



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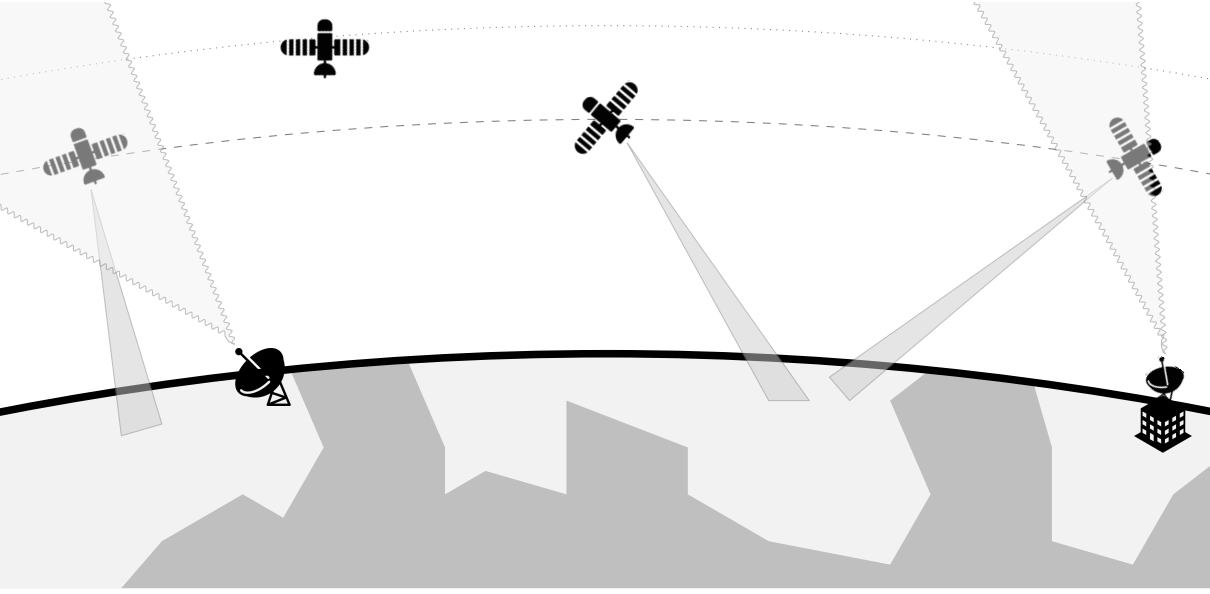
Visibility windows



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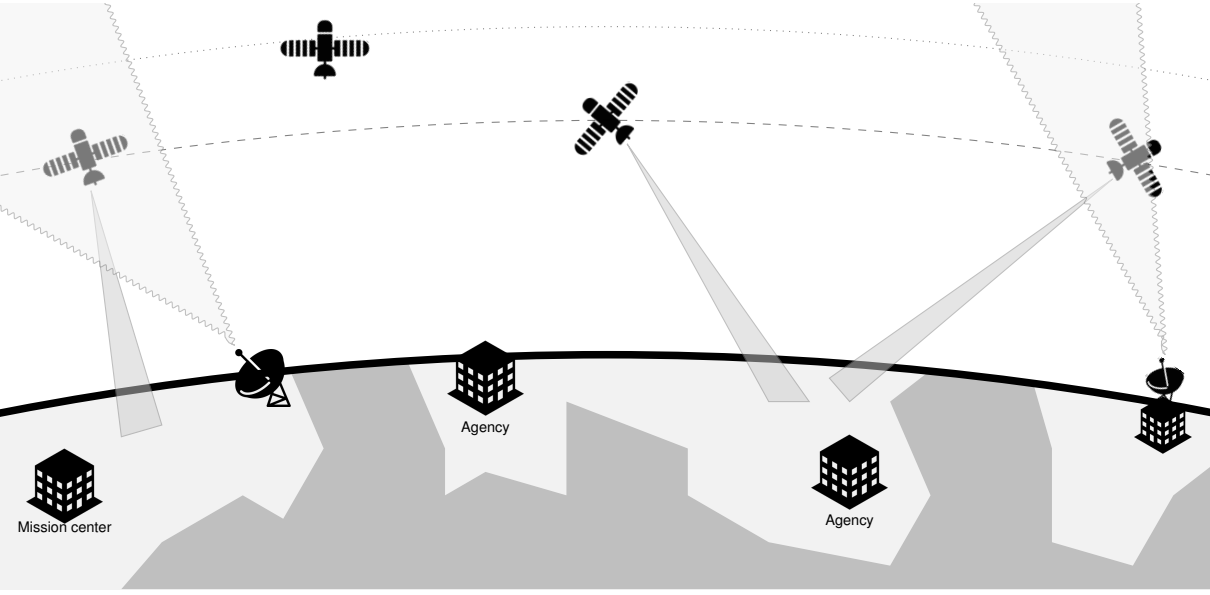
Other actors and stakeholders



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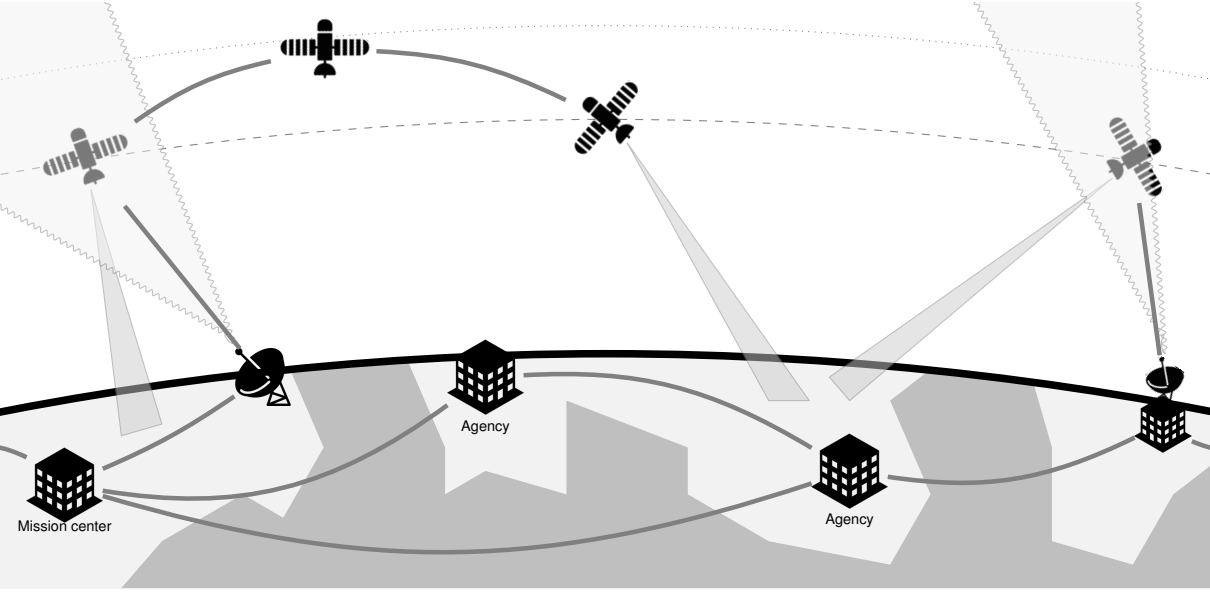
System organization



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  [Bastianelli et al., 2012; Budianto and Olds, 2004; Zhang et al., 2013]
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⚠ Models used for assessing performance are different from models used for assessing requirements/safety [SÁNCHEZ et al., 2017]

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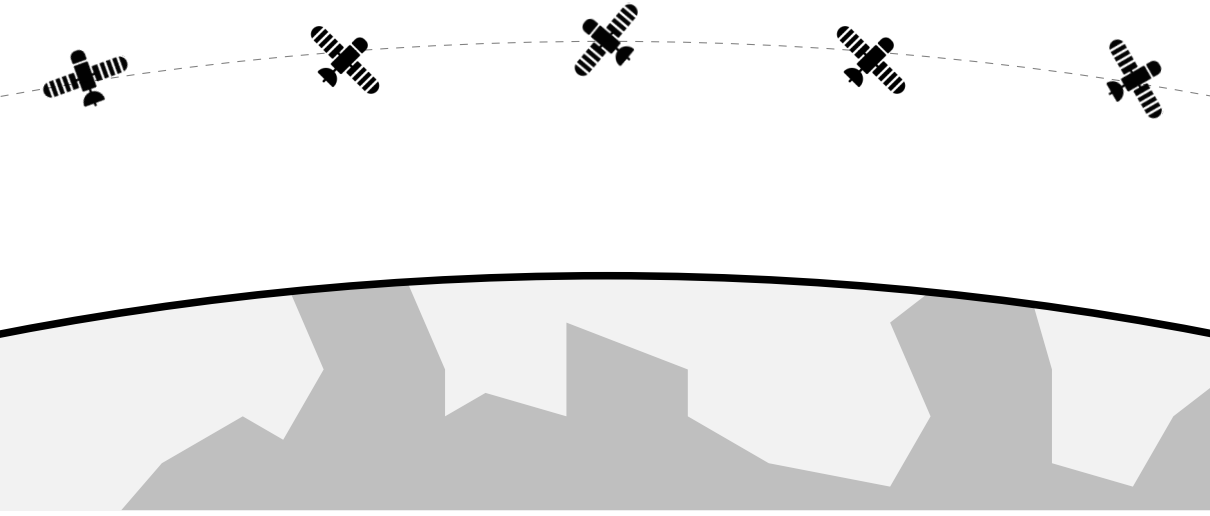

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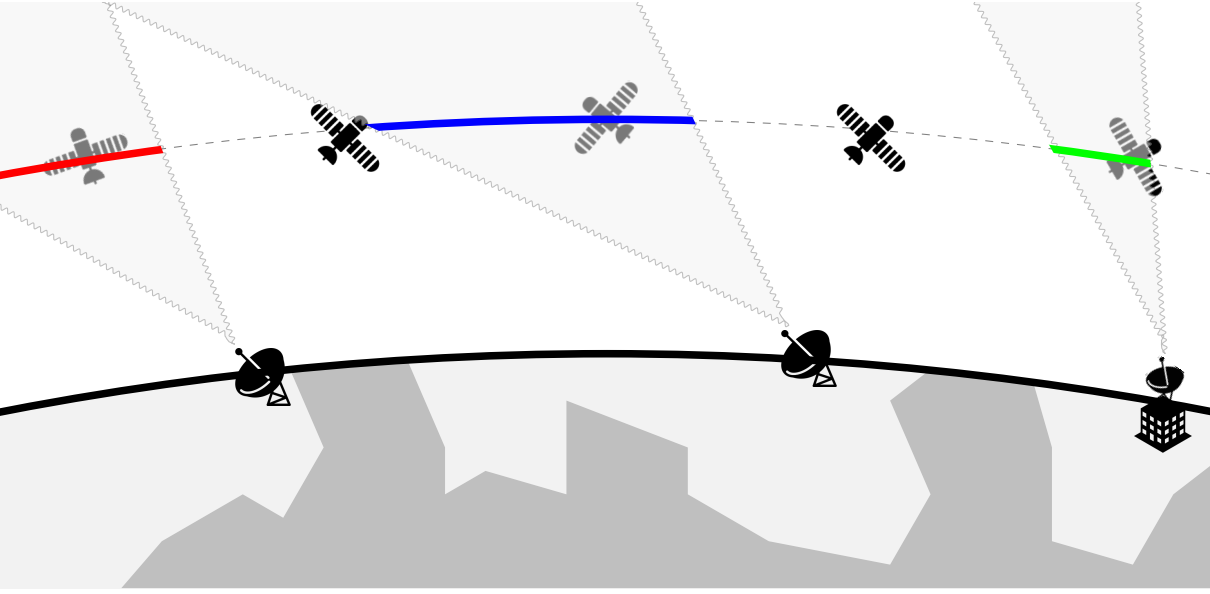

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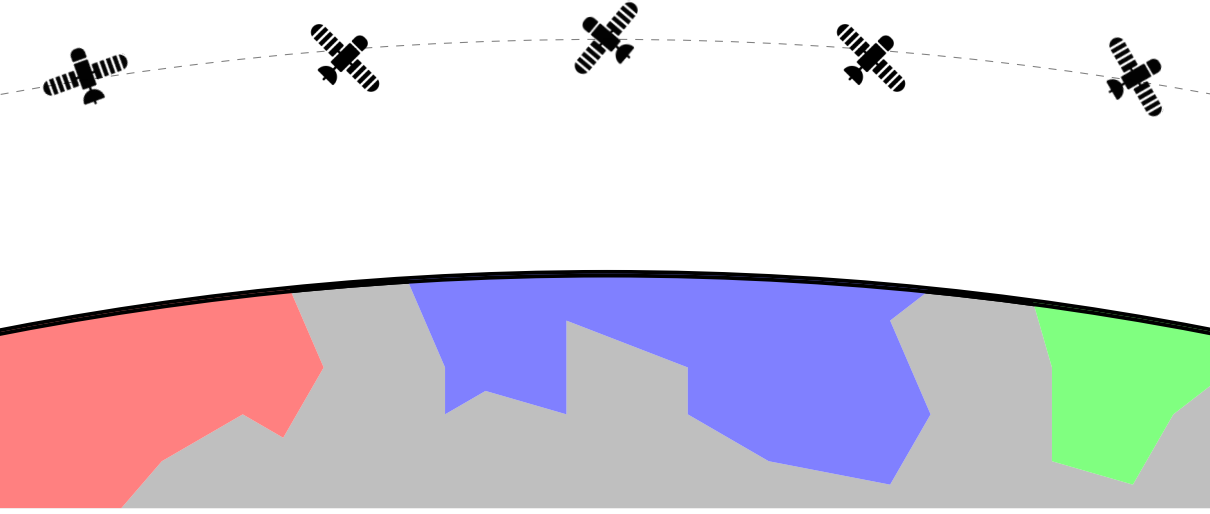

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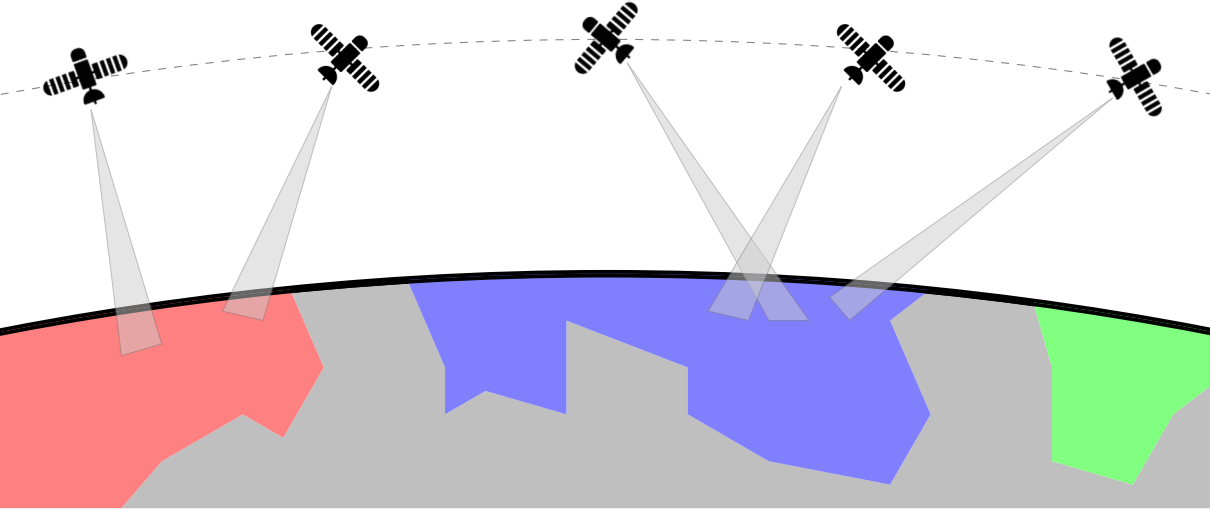

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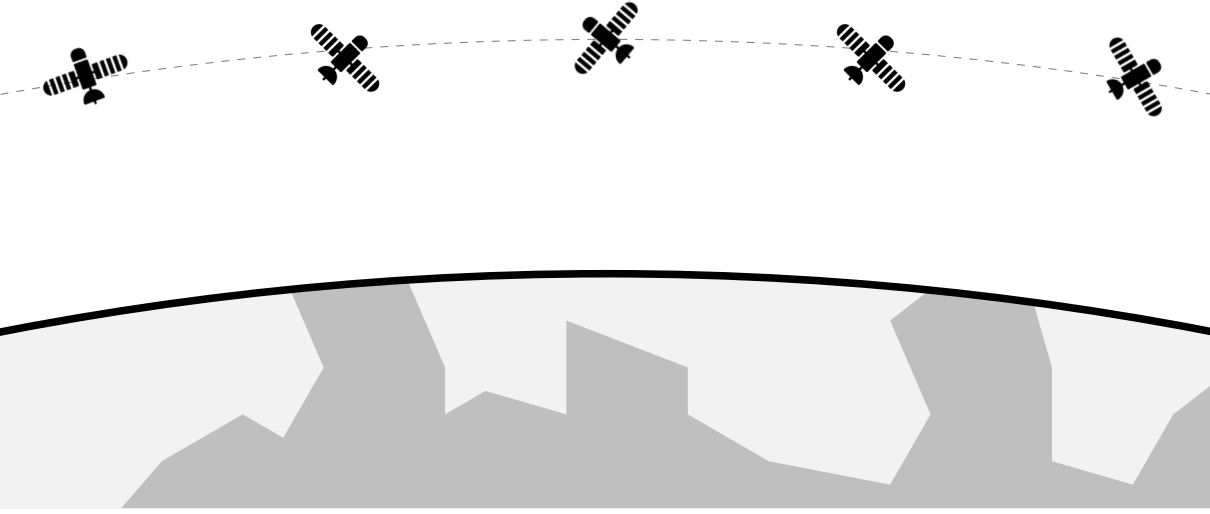
- *Centralized or decentralized procedures*, returning (near) optimal allocations
  - *e.g.* Auctions on orbit portions, geographic zone

Offline Operation Challenges

How to Schedule Tasks in a Multi-satellite and Multi-user Setting?



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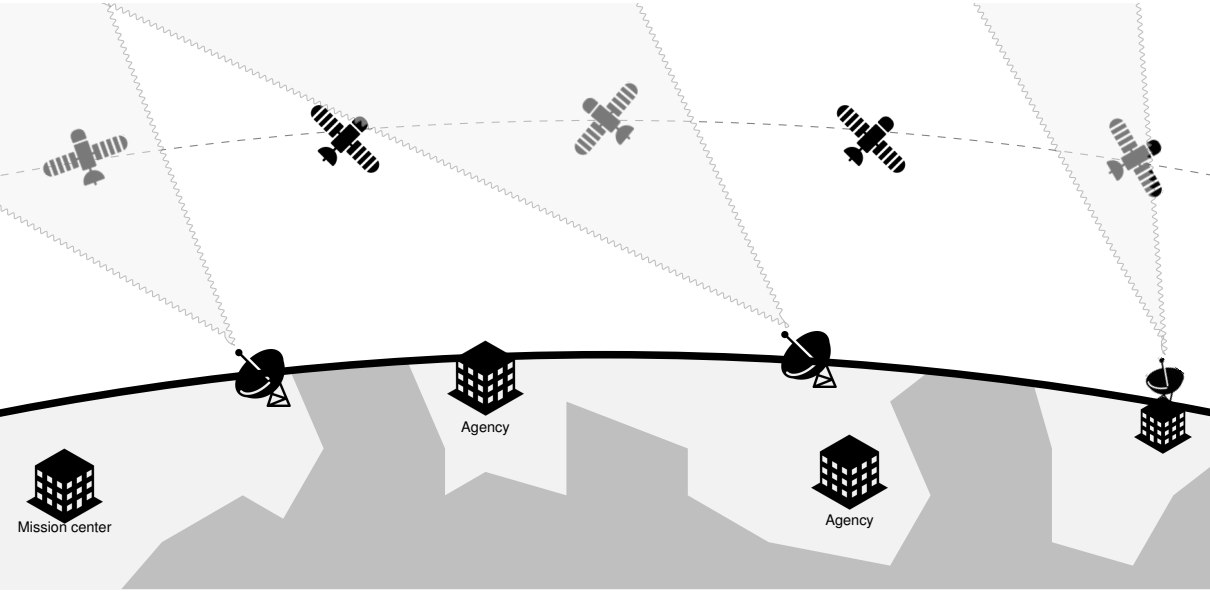

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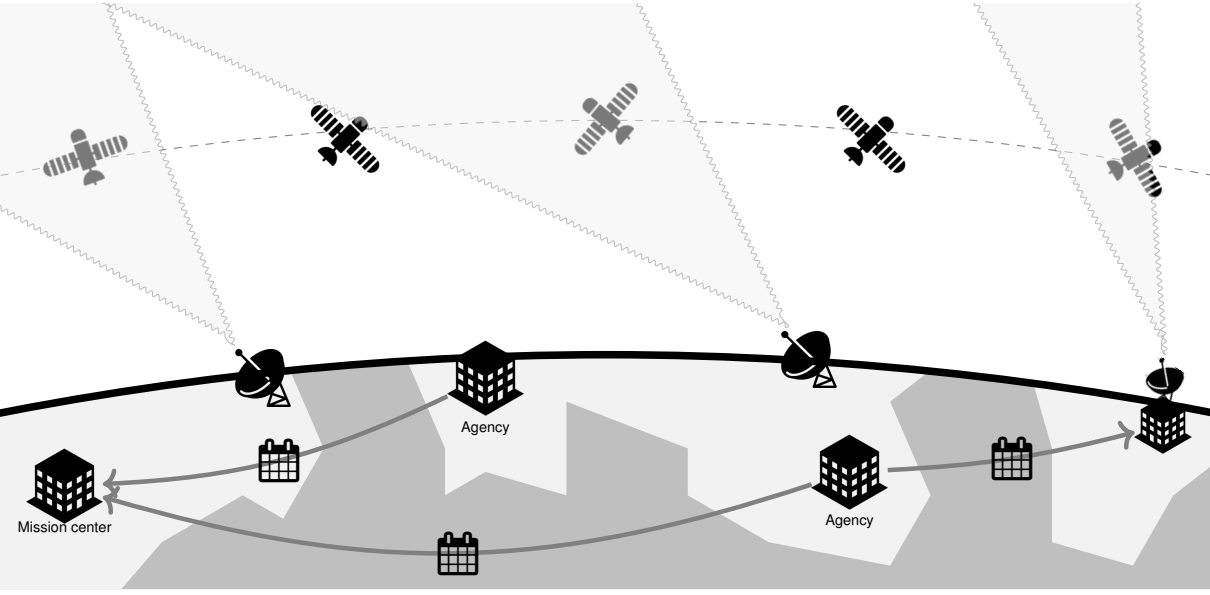

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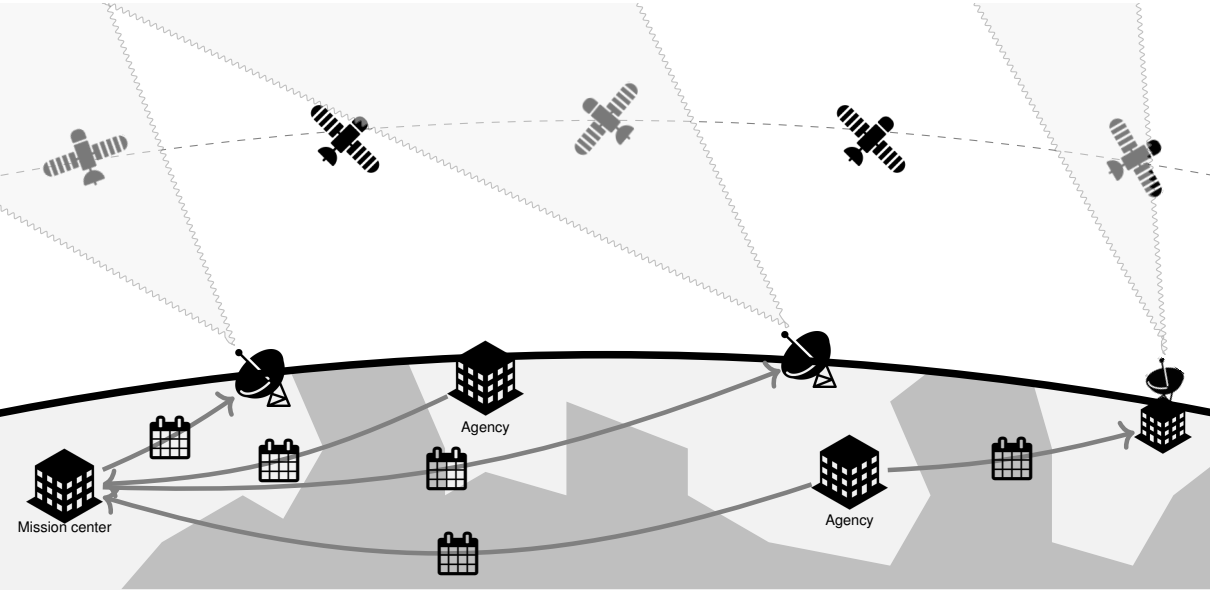

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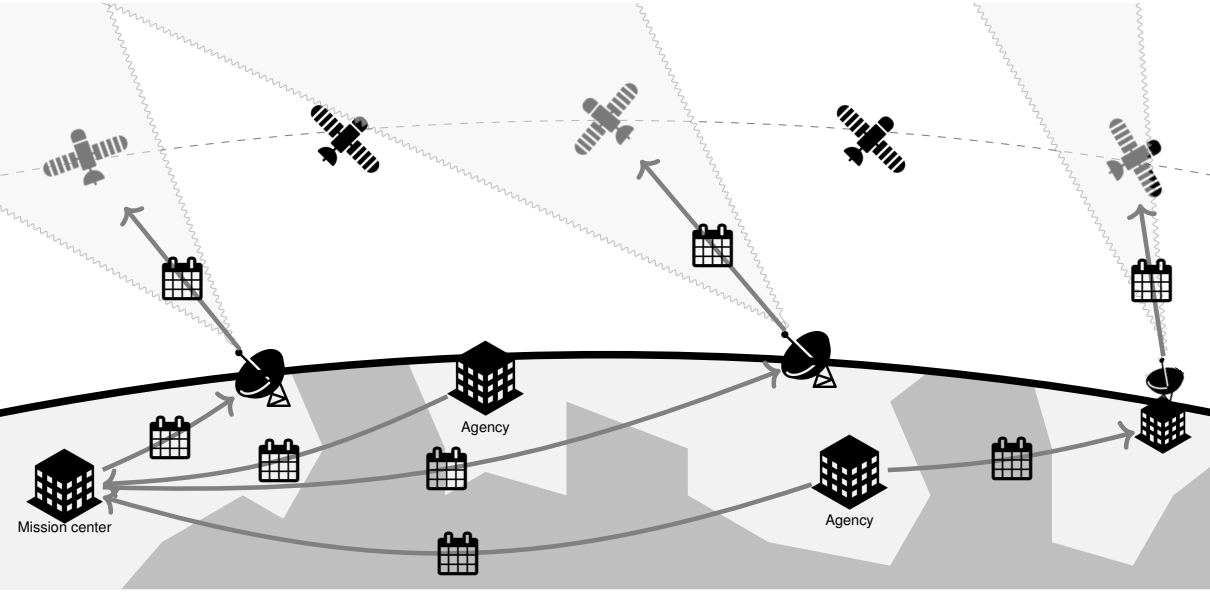

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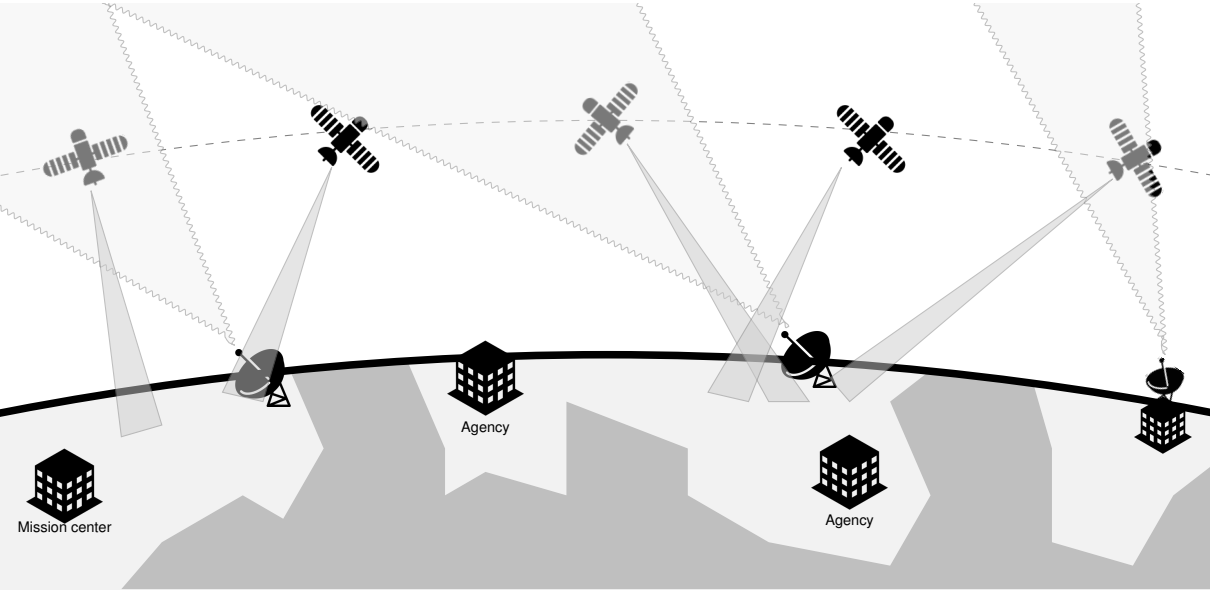

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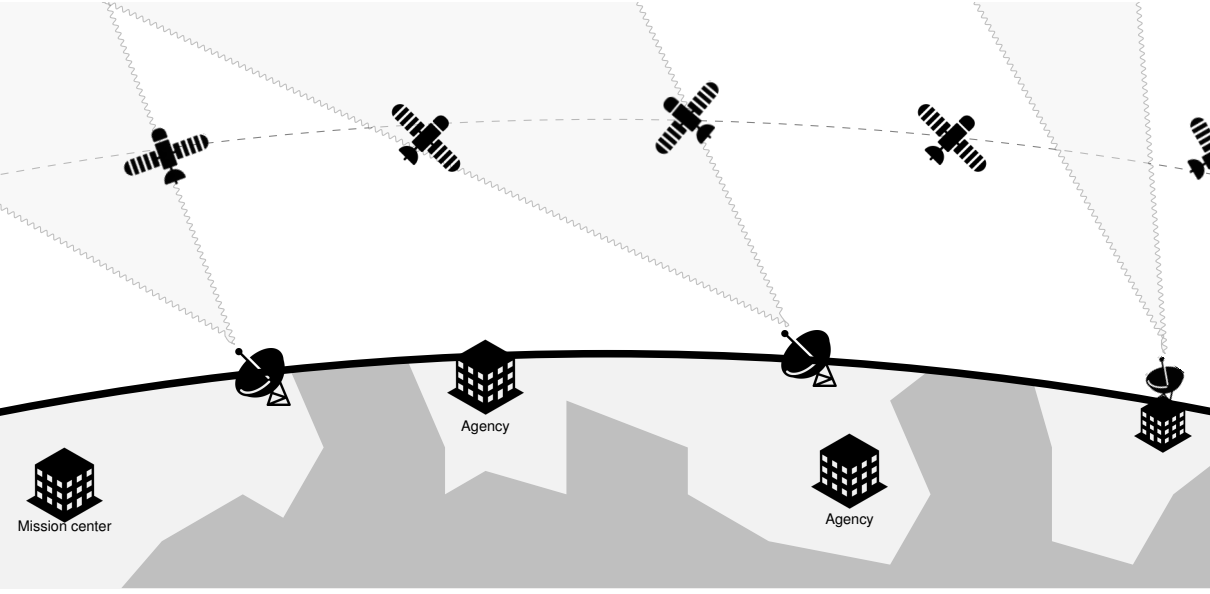

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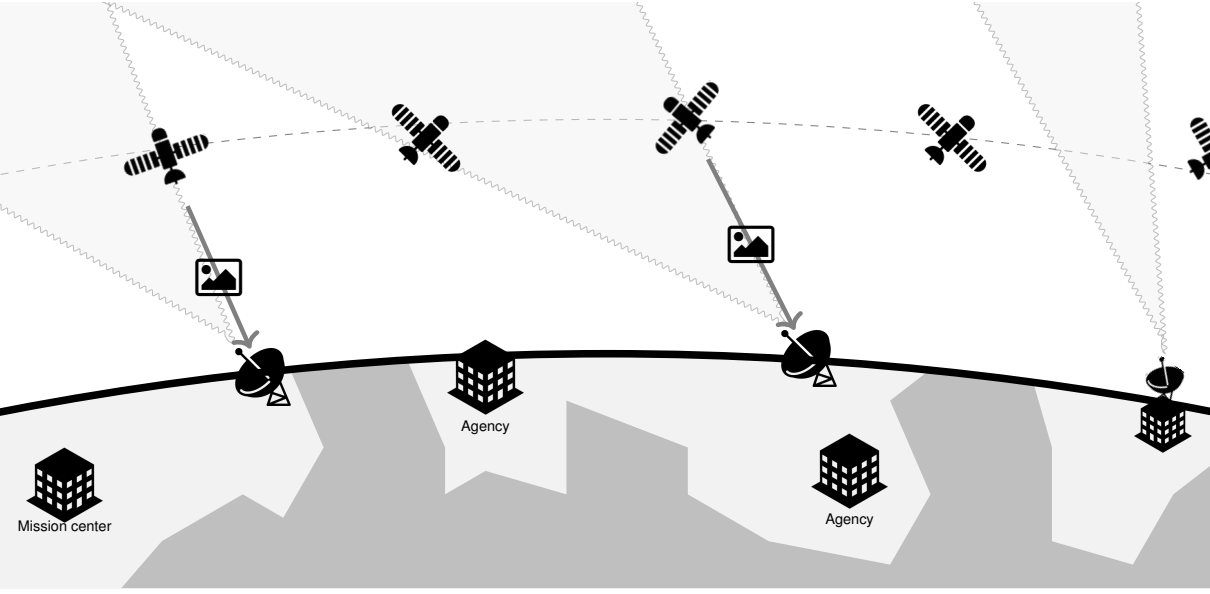

Offline Operation Challenges
Scheduling Observations

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- *Self-organization and heuristics* for *large scale* schedules [BONNET et al., 2015]
  - ⚠ No quality guarantees, yet?

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- *Beyond probabilities*
  - *Possibility Theory* [DUBOIS and PRADE, 2014] → increased decision robustness
  - ⚠ How to define deterministic rewards that consider requests of different types and priorities, while being combined into the chosen uncertainty measure?

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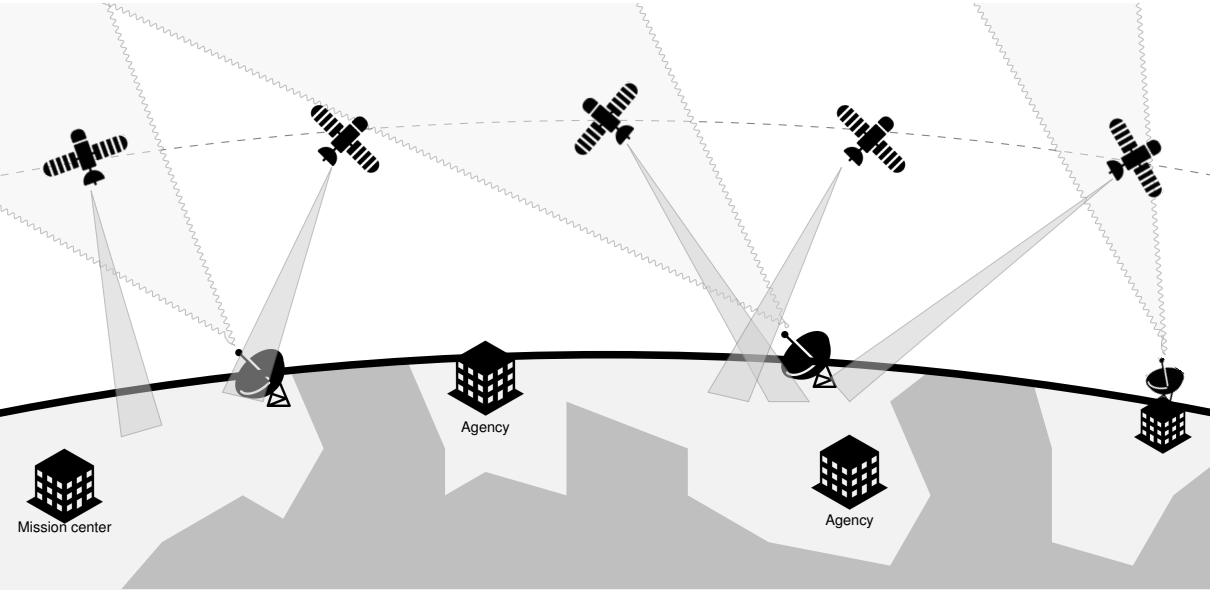
- *Game Theory* [SUN et al., 2018] and market design [DENIS et al., 2017], in more conflicting and non-cooperative settings

Online Operation Challenges

How to Adapt Activities when Facing Unpredictable Events?



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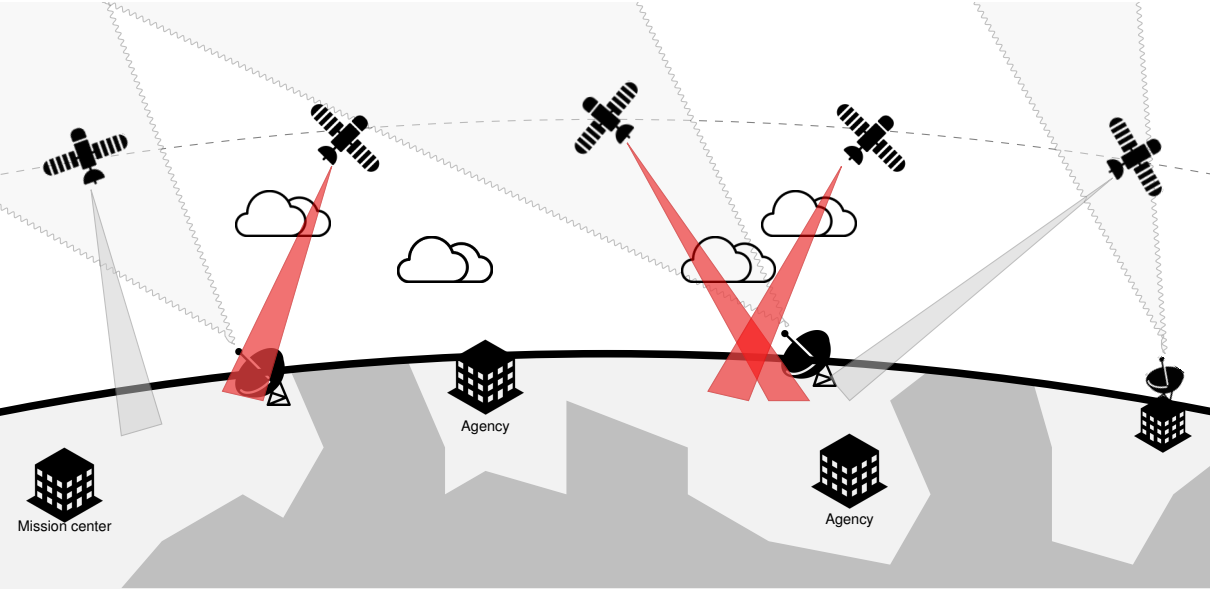

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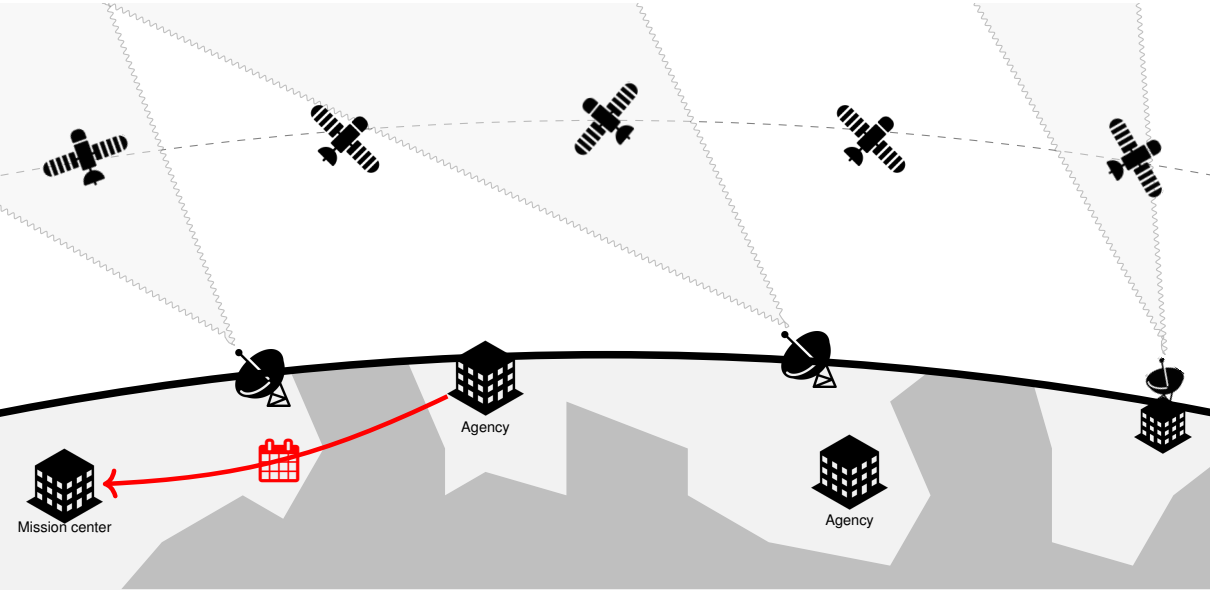

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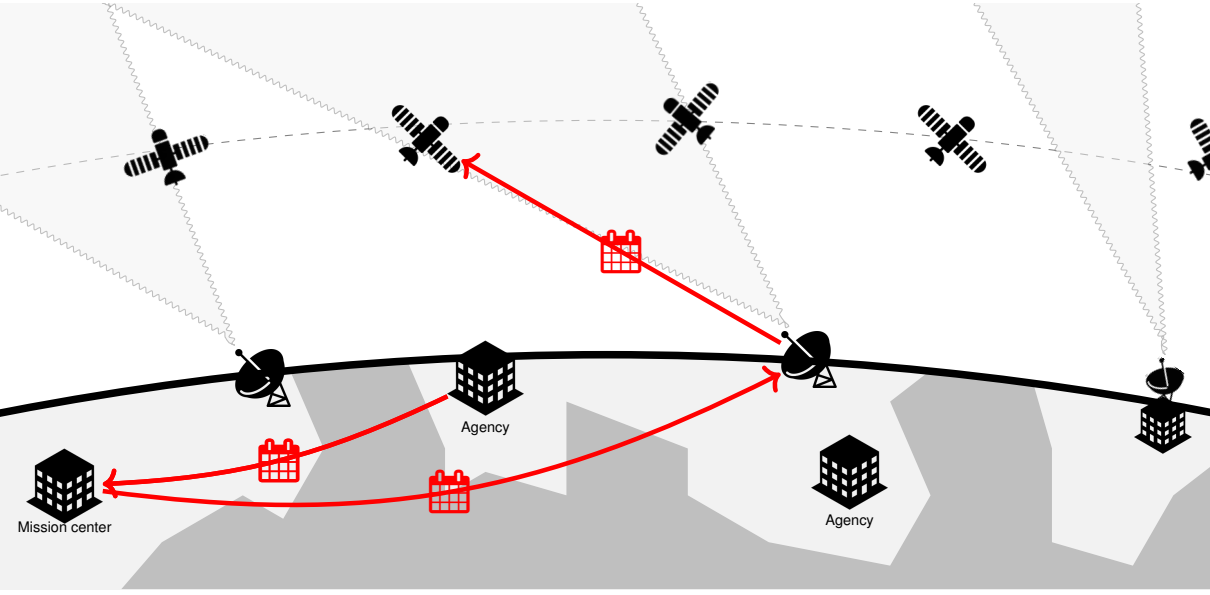

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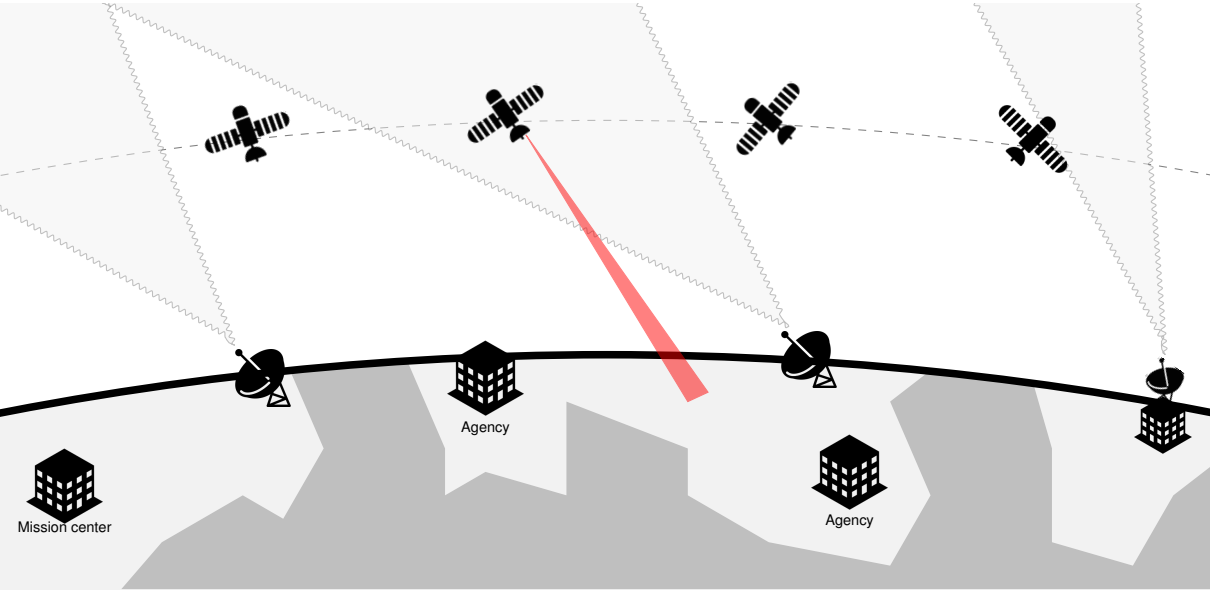

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- *On-board decision-making* and inter-agent cooperation
  - *Dynamic Distributed Constraint Optimization* (DynDCOP) [HOANG et al., 2016; RUST et al., 2020]
  - *Multiagent plan repair* techniques [KOMENDA et al., 2014]
  - *Dynamic consensus* techniques [FRANCESCHELLI and FRASCA, 2018; LI et al., 2014]
  - ⚠ Limited scalability and resilience to communication loss and asynchronicity [DIBAJI and ISHII, 2015; JOHNSTON, 2020; RUST et al., 2020]
  - ⚠ Strong requirements for on-board operations

Online Operation Challenges

Interaction and Protocols

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  - inter-satellite link
  - direct communication between mission centers
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  - *Epidemic communication protocols* [BONNET and TESSIER, 2007]
  - *Negotiation and coordination* between spacecraft agents [ARAGUZ et al., 2015; CAHOY and KENNEDY, 2017; SCHETTER et al., 2003]

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- *Multi-agent protocols* to answer questions like "which communication protocol should be used?", "when to communicate?", "which data to communicate and to who?", or "what is the value of an information?"
  - *Epidemic communication protocols* [BONNET and TESSIER, 2007]
  - *Negotiation and coordination* between spacecraft agents [ARAGUZ et al., 2015; CAHOY and KENNEDY, 2017; SCHETTER et al., 2003]

⚠ Strong requirements for on-board operations

Concluding Remarks

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Many challenges in EOS constellations and related applications...

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Many challenges in EOS constellations and related applications...
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- Coordination, Organisations, Institutions, and Norms
- Engineering Multiagent Systems
- Knowledge Representation, Reasoning, and Planning
- Learning and Adaptation
- Markets, Auctions, and Non-Cooperative Game Theory
- Modelling and Simulation of Societies
- Robotics
- Social Choice and Cooperative Game Theory

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Autonomous Agents and Multiagent Systems Challenges in Earth Observation Satellite Constellations

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