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DOMINO

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Autonomous Federation of Earth Observation Constellations

An End-to-End Demonstrator based on the DOMINO Architecture

Cyrille De Lussy[1] Stéphane Derrien[2] Marie Devant[2] Jean-Loup Farges[3] Jonathan Guerra[1]
Philippe Pavero[1] *Gauthier Picard*[3] Cédric Pralet[3] Jakub Rezler[4] Raivis Skadiņš[5]

gauthier.picard@onera.fr

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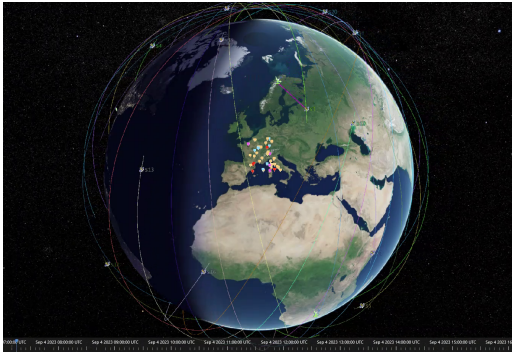
[1]Airbus Defence and Space [2]Cap Gemini [3]DTIS, ONERA, Université de Toulouse [4]ITTI [5]Tilde

The Challenge of Modern Earth Observation

[FARGES et al., 2024]

- **Context:** Massive proliferation of small satellites and heterogeneous constellations
- **Issue:** Siloed missions lead to inefficient resource utilization and complex, manual tasking
- **Objective:** Transition to a user-centric, autonomous federation (DOMINO-E)

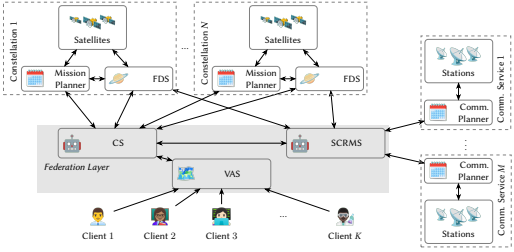


The DOMINO-E Architecture

https://domino-e.eu/

The federation relies on three core autonomous services:

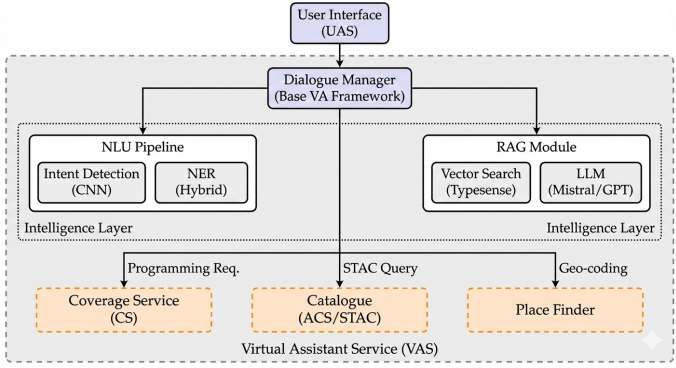
1. **VAS (Virtual Assistant Service):** Natural language interface for user requests
2. **CS (Coverage Service):** Orchestrates multi-mission area partitioning
3. **SCRMS (Service Control & Resource Management Service):** Optimizes ground station (GSaaS) bookings



VAS: Cognitive Interaction

[Skadiņš et al., 2015]

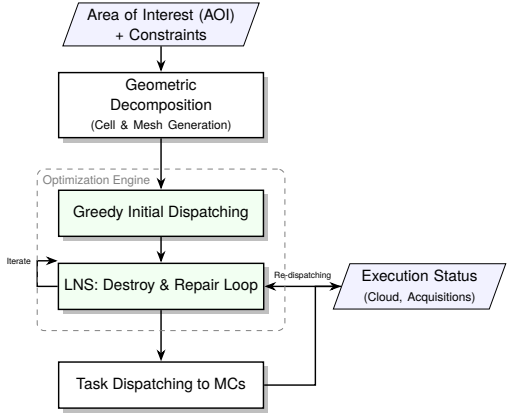
- Bridges the gap between technical mission constraints and human intent
- Leverages LLMs for intent classification and RAG for querying mission-specific catalogues



CS: Dynamic Mesh Dispatching

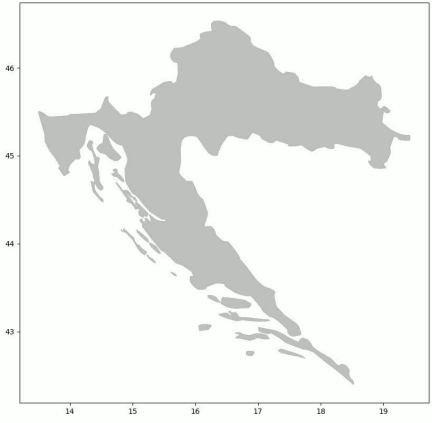
[PRALET et al., 2025]

- **Methodology:** Decomposes large area requests into atomic cells
- **Optimization:** Uses Large Neighborhood Search (LNS) to minimize task completion time and redundant area



CS: Dynamic Mesh Dispatching (cont.)

[PRALET et al., 2025]



SCRMS: Ground Segment Optimization

[WILLOT et al., 2025a,b]

- Addresses the probabilistic nature of Ground Segment as a Service (GSaaS)
- Solves Multi-criteria Mixed-Integer Linear Programming (MILP) models (ORTools implementation)
- **Logic:** Minimize Cost (1) and Jamming (2) s.t. (3)

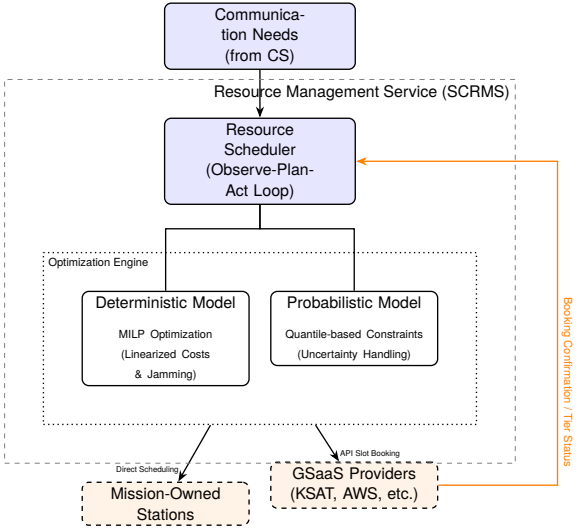
$$C = \sum_{s\in\mathcal{PU}} \sum_{i=1}^{N} \sum_{l=1 \mid s=cm(i,l)}^{L_i} c_s^t d_{i,l} x_{i,l} + \sum_{s\in\mathcal{PP}} \sum_{i=1}^{N} \sum_{l=1 \mid s=cm(i,l)}^{L_i} c_s^0 x_{i,l} + \sum_{s\in\mathcal{PPC}} c_s^0 \max(0, \sum_{i=1}^{N} \sum_{l=1 \mid s=cm(i,l)}^{L_i} x_{i,l} - Y_s) \tag{1}$$

$$J = \sum_{i=1}^{N} \sum_{l=1}^{L_i} f_{i,l} x_{i,l} + \sum_{i=1}^{N-1} \sum_{l=1}^{L_i} \sum_{j=i+1}^{N} \sum_{m=1}^{L_j} b_{i,l,j,m} x_{i,l} x_{j,m} \tag{2}$$

$$\sum_{l=1 \mid k\in\mathcal{Z}_{i,l}}^{L_i} d_{i,k,l} x_{i,l} \geq D_{i,k}, \forall i \in \{1,\ldots,N\}, \forall k \in \{1,\ldots,K_i\} \tag{3}$$

SCRMS: Ground Segment Optimization (cont.)

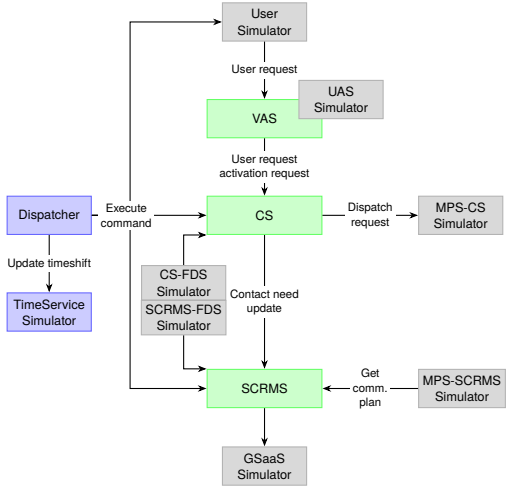
[Willot et al., 2025a,b]



Demonstration: Sichuan Flooding Scenario

https://www.youtube.com/watch?v=I2biwBIydZ0

- **Phase 1:** User inputs flood-zone coordinates via VAS
- **Phase 2:** CS dynamically partitions area across CO3D and Pléiades Neo
- **Phase 3:** SCRMS coordinates multi-constellation downlinks



Conclusion

- The DOMINO-E project has successfully demonstrated the feasibility and operational benefits of a **multi-mission federation layer** for EO
- **Autonomous** ecosystem: the ”DOMINO” architecture
- Results obtained across the three core services consistently validate the project’s objectives:
  1. **Accessibility:** The VAS reduced tasking time by 40% via natural language, democratizing access for non-experts
  2. **Efficiency:** The CS utilized LNS algorithms to reduce area waste to 20%, significantly optimizing large-scale monitoring compared to static methods
  3. **Scalability:** By transitioning to a GSaaS model, SCRMS achieved 100% fulfillment of X-band communication needs
- **”Closed-Loop” capabilities** showcased in the End-to-End demonstration highlight the system’s ability to autonomously re-dispatch tasks in response to real-world uncertainties
- Ultimately, DOMINO-E provides a **scalable framework**, establishing a foundation for a more responsive and efficient space segment

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This work has been performed within the DOMINO-E project which received funding from the European Union's Horizon Europe Programme for Research and Innovation under Grant Agreement n°101082230.

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Thank you for your attention!
Any question?
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