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Knowledge Base for Distributed Spacecraft Mission Design Using the Trade-space Analysis Tool for Constellations (TAT-C)

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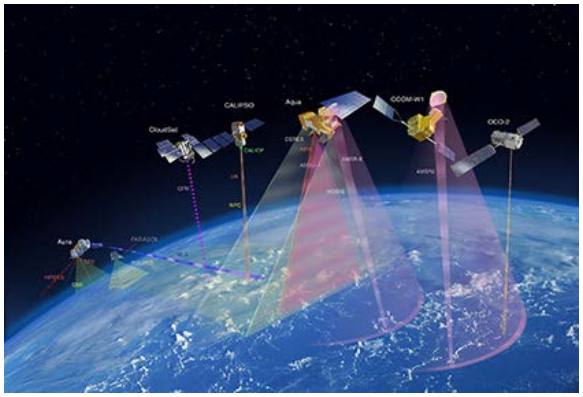
NASA Earth Science Challenges

Landsat 8 (Source)

Traditional EO Mission:

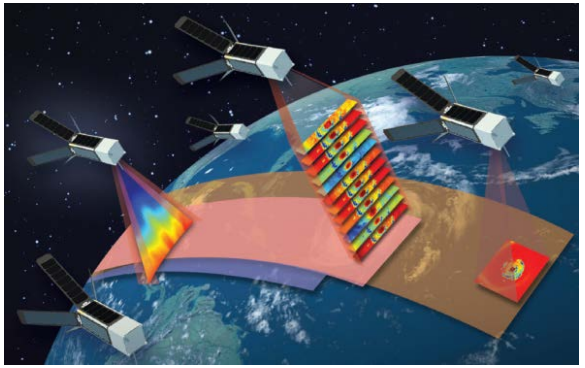
- Monolithic platform
- Direct value from collected data:
  - Operational Land Imager
  - Thermal Infrared Sensor



Afternoon Constellation (Source)

Novel EO "Mission":

- Coordinated platform
- Emergent value from correlated data
  - 10+ instruments
  - Spatial/temporal correlation



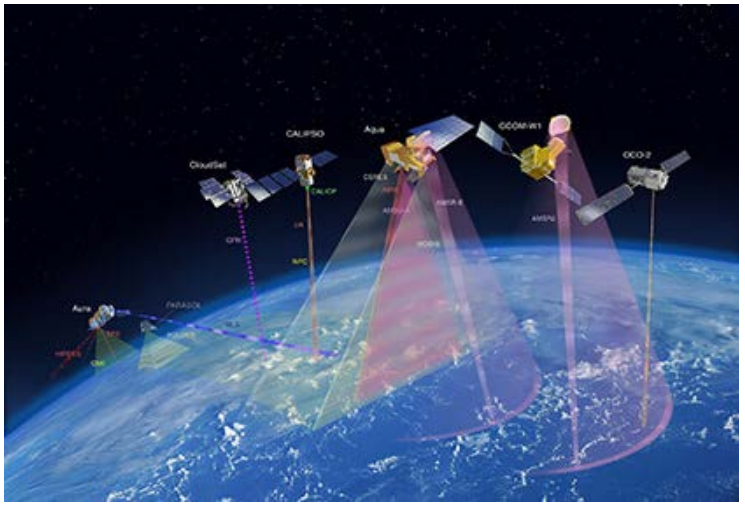
TROPICS (Source)

Future EO Mission:

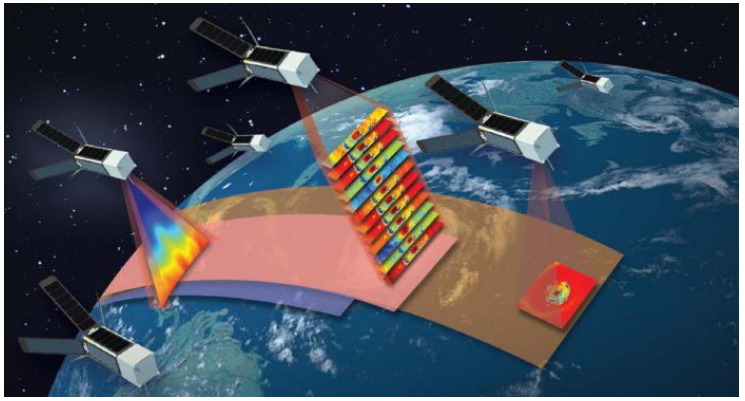
- Distributed platform
- Emergent value from composed data
  - Control member spacecraft

Distributed Spacecraft Missions (DSM)

- **DSMs** leverage multiple spacecraft to achieve one or more common goals
- Potential benefits:
  - Multiple measurements in spatial, spectral, temporal, and angular dimensions
  - Mission flexibility & robustness
  - Cost effectiveness
- Potential risks:
  - New technology & operations
  - Emergent system performance
  - “Robust-yet-fragile” behaviors



Afternoon Constellation (Source)

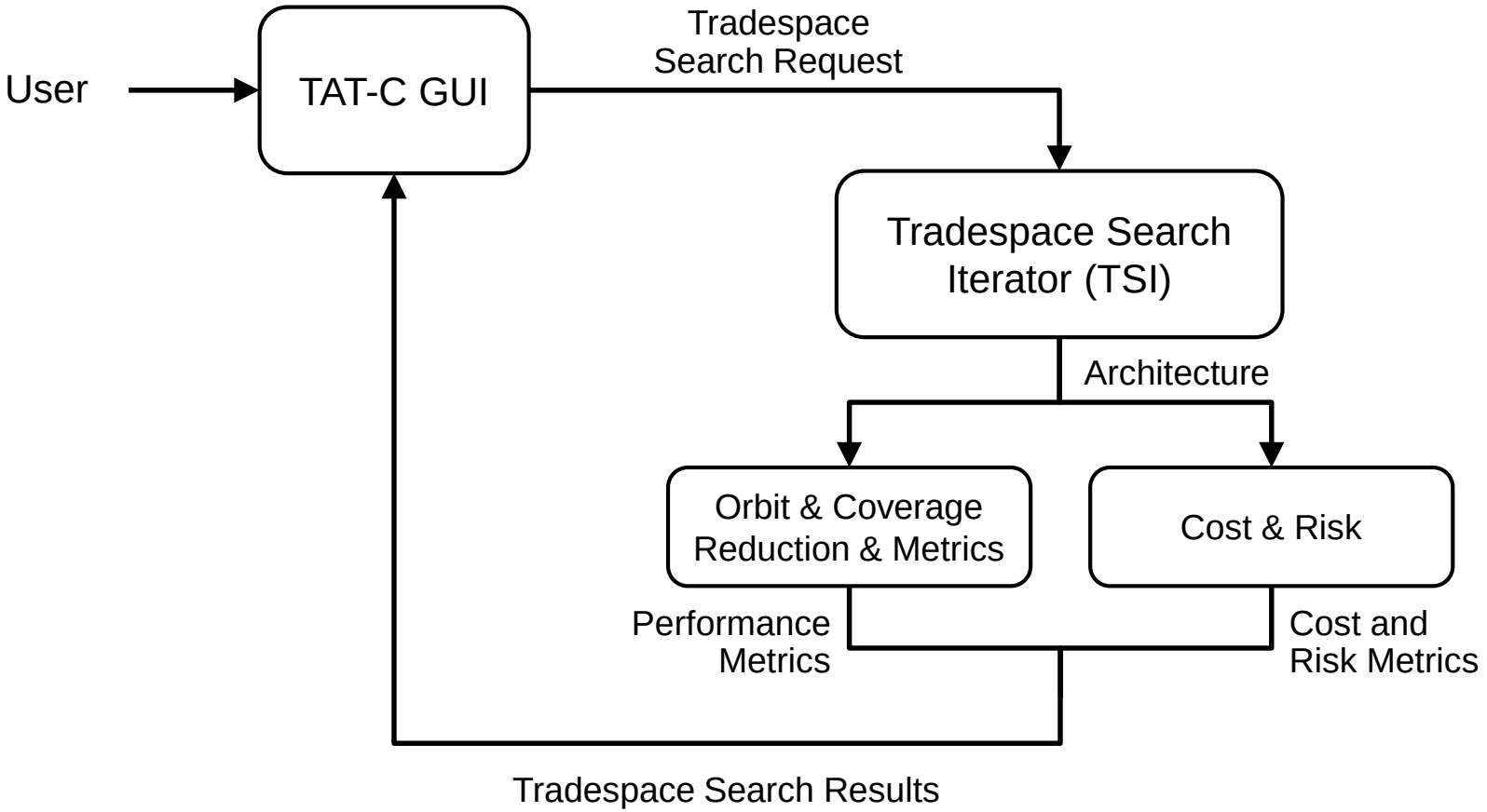


TROPICS Mission Concept (Source)

Research Challenges

- Assess anticipated performance, costs, and risks of alternative DSM concepts in pre-Phase A analysis
  - *Tradespace Analysis Tool for Constellations (TAT-C)*
  - Combinatorial DSM tradespaces are cognitively and computationally difficult to search effectively
- Represent and ultimately reason on accumulated **knowledge** from tradespace analyses
  - Knowledge Base for TAT-C
  - **How can knowledge base services augment DSM tradespace search activities in TAT-C?**

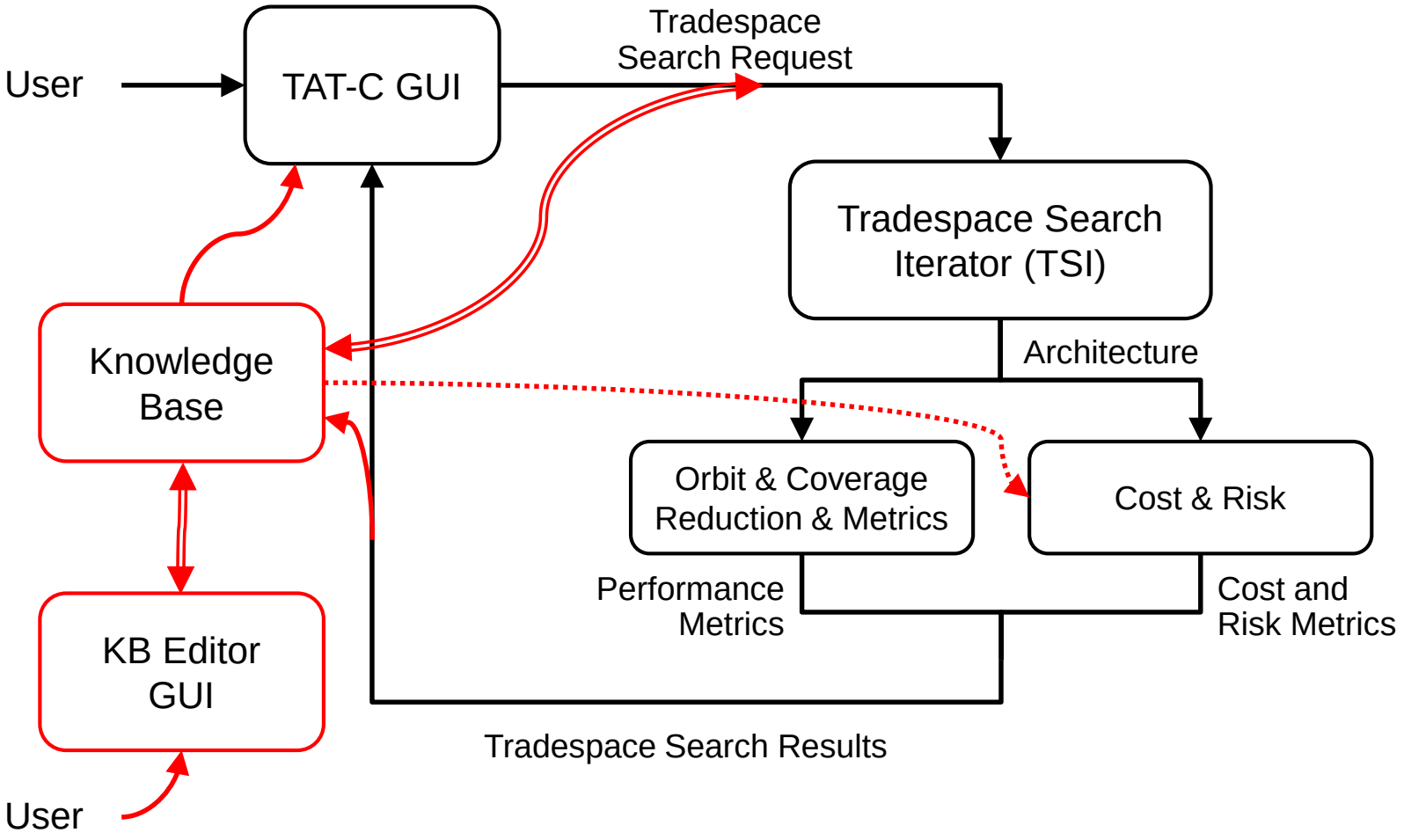
TAT-C Architecture



Knowledge Base

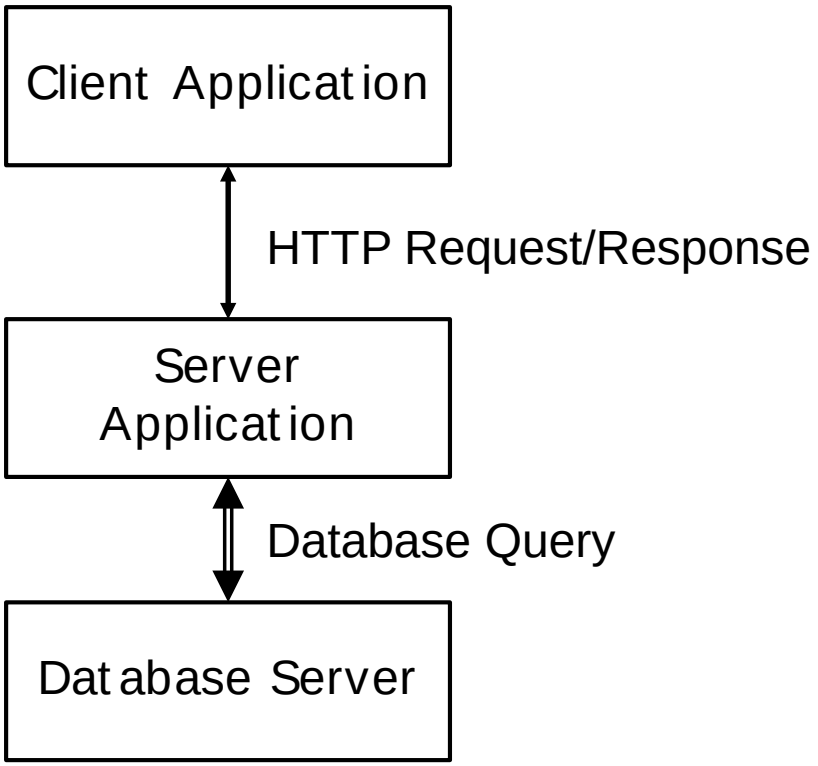
- Cumulative, common repository of information and meta-information about DSMs
  - Knowledge representation goes beyond data structure and syntax to also incorporate semantics and meaning
  - Loosely coupled with TAT-C, generally applicable to DSMs
- Preliminary services and features:
  - Store and retrieve tradespace search requests
  - RESTful application programming interface (API)
  - Browser-based graphical user interface (GUI)

TAT-C Architecture with KB

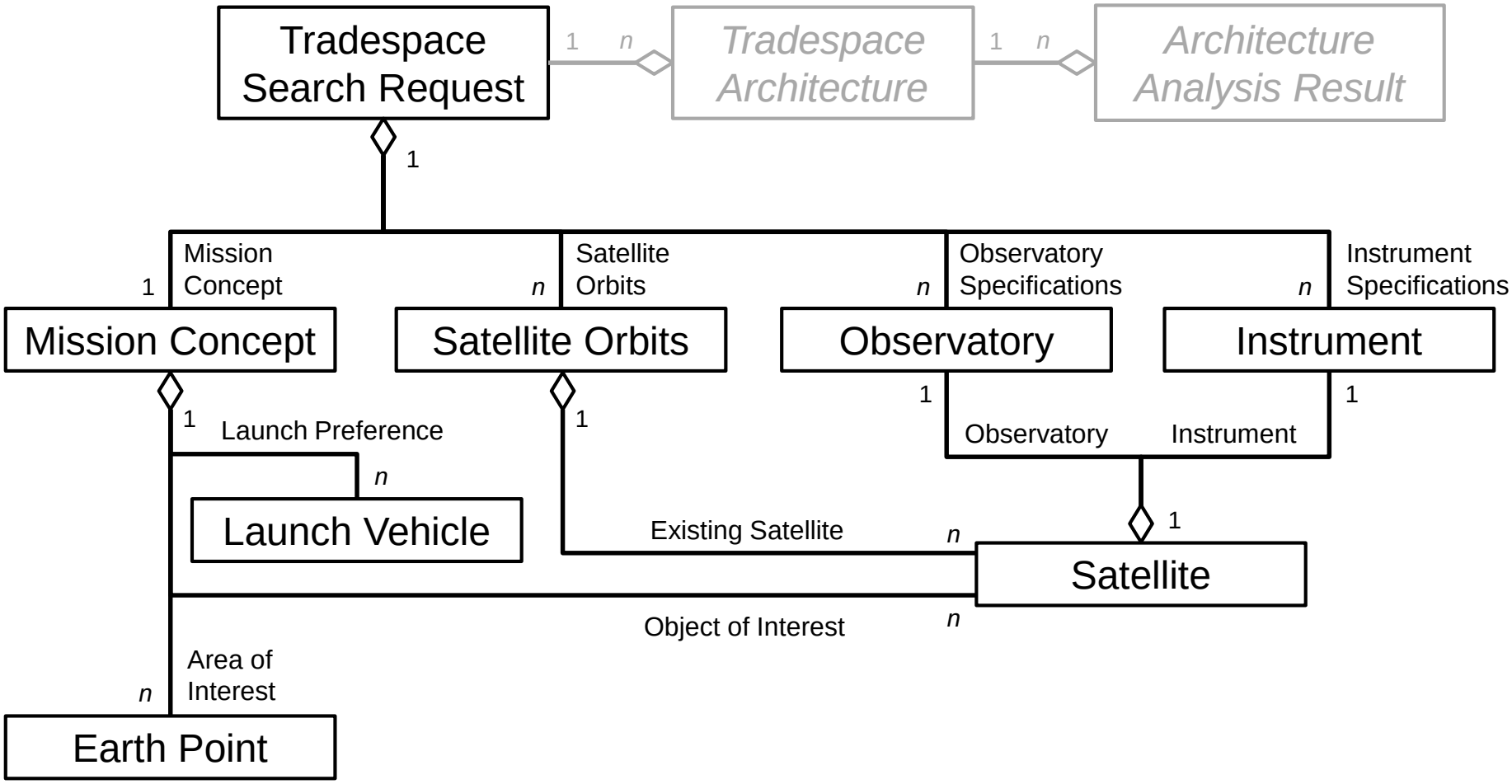


Knowledge Base Architecture

- Layered architecture: each component can be hosted independently
- Client: request KB services
  - TAT-C, KB editor, or other
- Server: provide KB services
  - Store/retrieve data via queries
  - Reason/infer based on rules
- Simple HTTP API
  - Universal transport protocol
  - RESTful: stateless requests



TAT-C Object Models / Collections



Example: Earth Point Object

Earth Point
String name double latitude double longitude double altitude String[] commBands

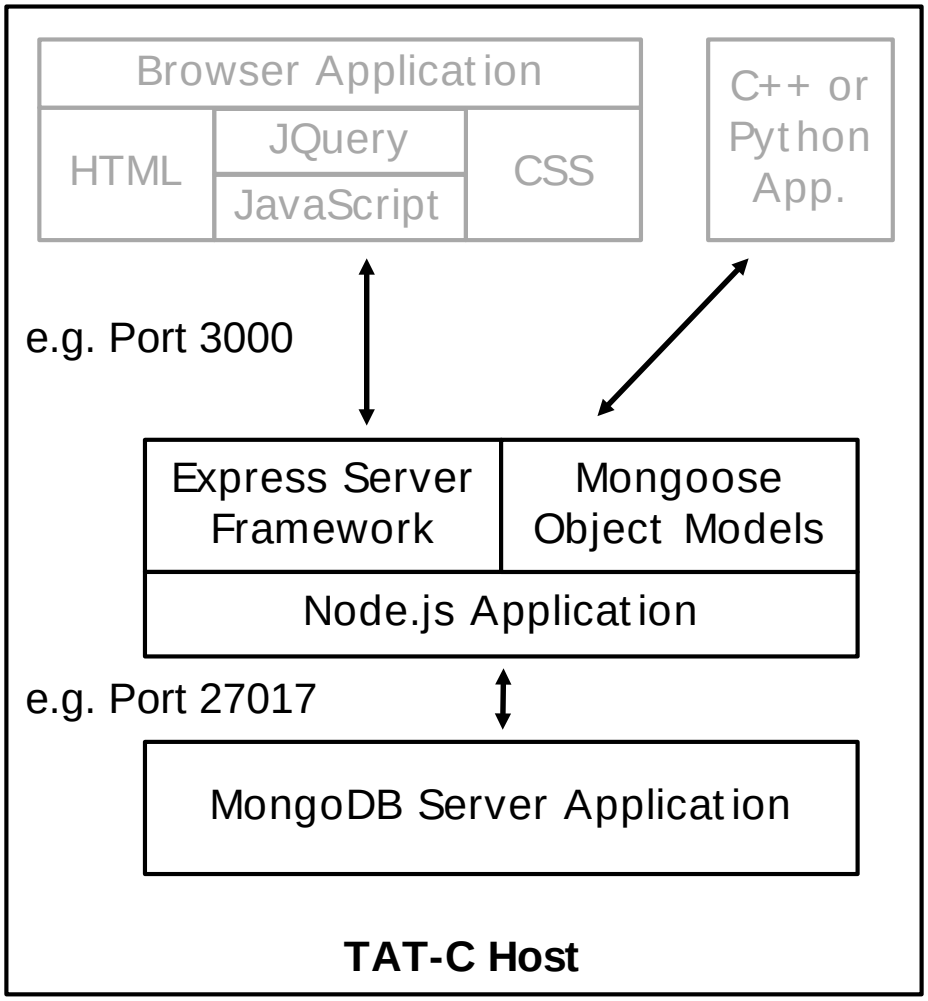
KB JSON Format

```
==============
{
  "name": "Stevens",
  "latitude": 40.7425,
  "longitude": -74.0268
  "altitude": 0.01,
  "communicationBands": ["S", "X"]
}
```

TAT-C ASCII Format

```
=================
40.7425 -74.0268 0.01 S X
```

Prototype KB Implementation



- Modified “MEAN” stack:
  - MongoDB database
  - Express web server
  - Node.js application platform
- Leverage common syntax for major components
  - JavaScript language
  - JavaScript Object Model (JSON) serialization
- Limiting to single (local) host addresses challenges to manage access control

Basic KB Services

Service	Method	API Route	Description
List	GET	/api/collection	Lists all models in a collection Optional: selection/filter criteria
Create	POST	/api/collection	Creates a new model in a collection
Read	GET	/api/collection/:id	Reads a model in a collection specified by a unique identifier Optional: output in TAT-C
Update	PATCH	/api/collection/:id	Updates an existing model in a collection specified by a unique identifier
Delete	DELETE	/api/collection/:id	Deletes an existing model in a collection specified by a unique identifier

Example List Service

- Request:

```
GET  http://localhost:3000/api/earthPoints
```

```
|--method--|---host---|port|-----route-----|
```

- Response:

```
[
  {"_id":"59270b73ccb6af081f728cf1","name":"Stevens"},
  {"_id":"59271344ccb6af081f728cf2","name":"Goddard"},
  {"_id":"59271349ccb6af081f728cf3","name":"MIT"},
  {"_id":"5927134fccb6af081f728cf4","name":"BAERI"}
]
```

Example Read Service

- Request:

```
GET http://localhost:3000
/api/earthPoints/592...cf1
```

- Response:

```
{
  "_id":"592...cf1",
  "longitude":-74.0268,
  "latitude":40.7425,
  "altitude":0.01,
  "name":"Stevens",
  "commBands":["S","X"]
}
```

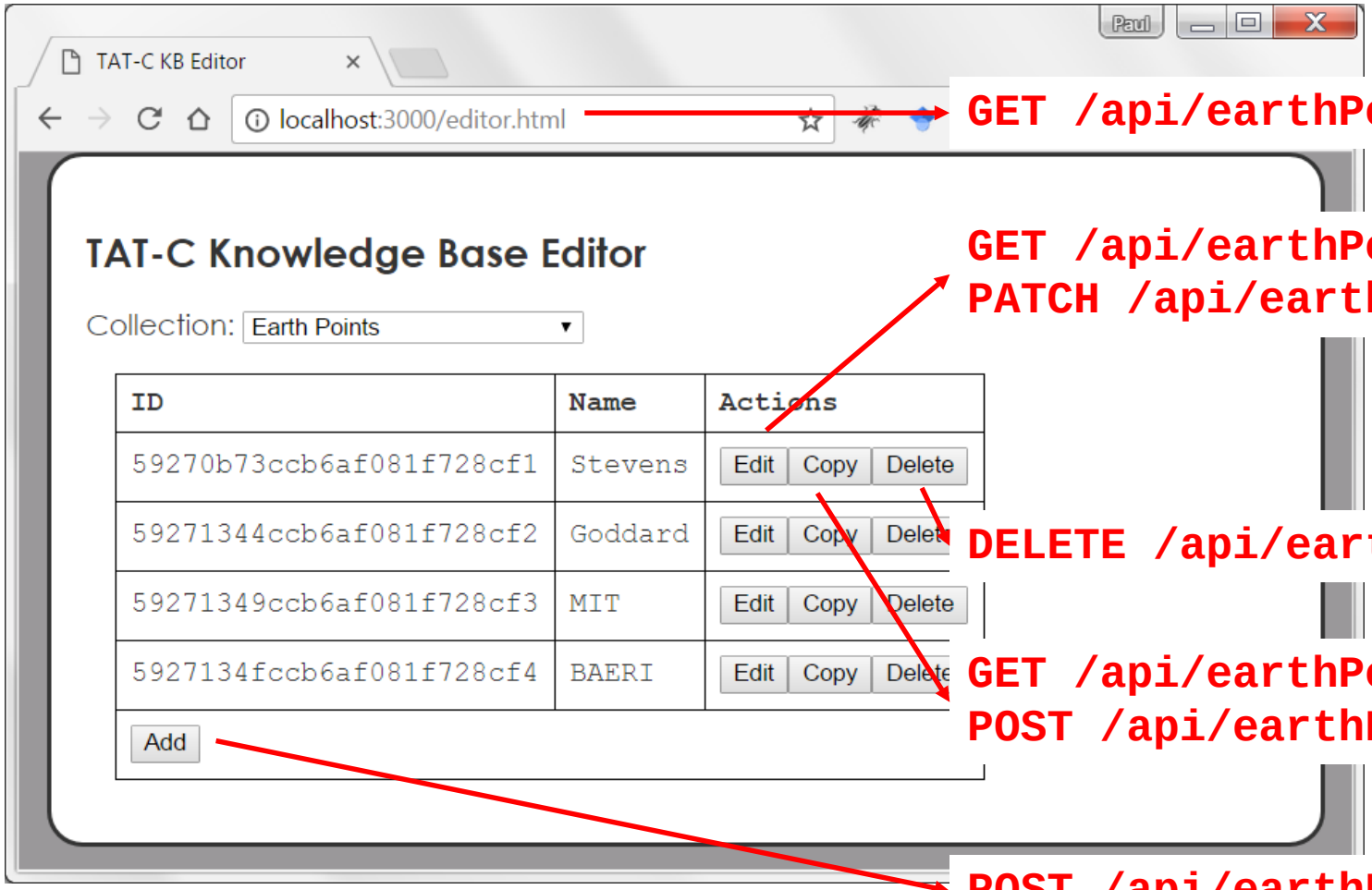
- Request:

```
GET http://localhost:3000
/api/earthPoints/592...cf1
?format=tatc
```

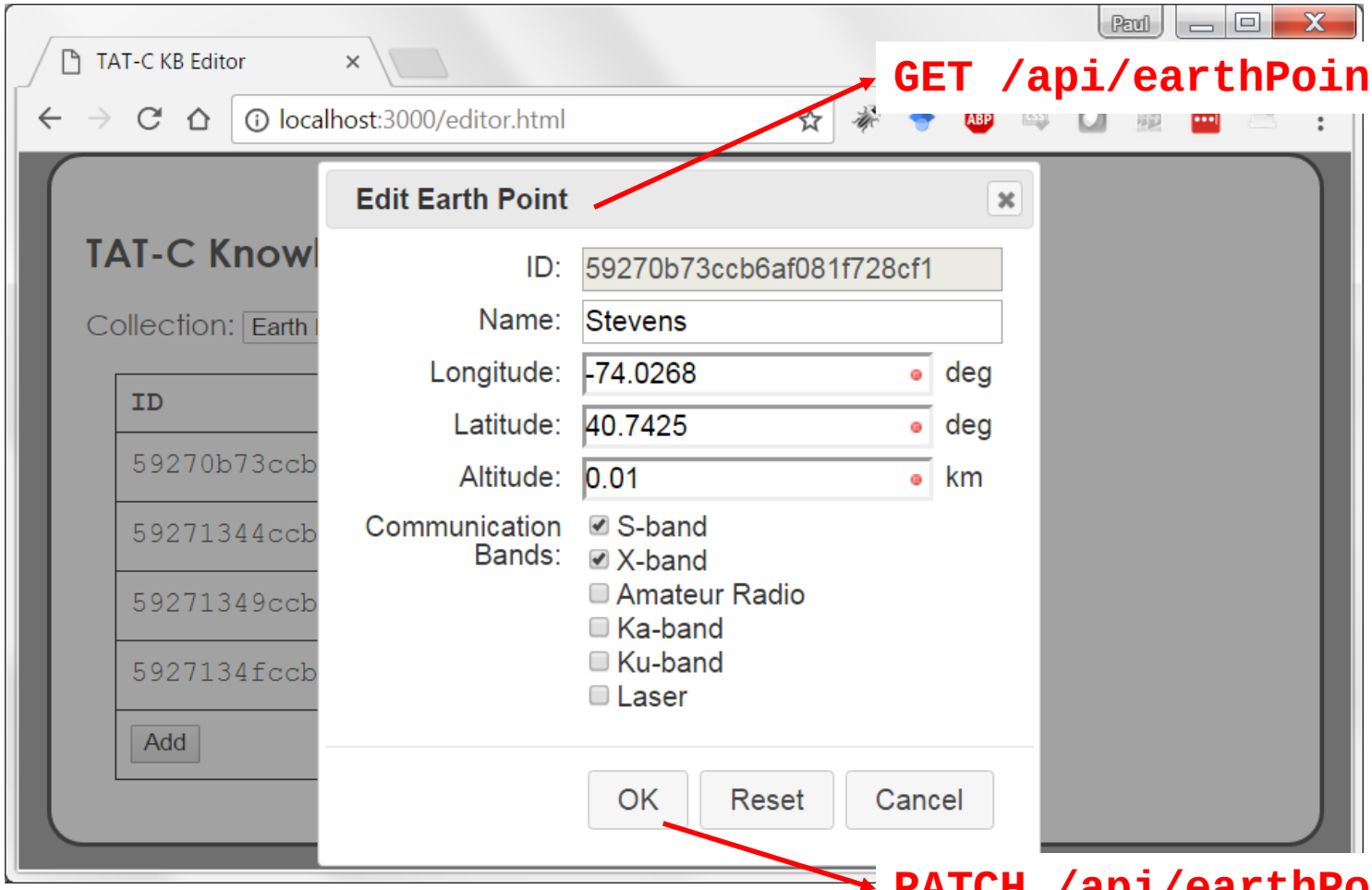
- Response:

```
40.7425 -74.0268 0.01 S X
```

Prototype KB Editor



Prototype KB Editor



Summary

- DSMs have significant potential to improve and enable future Earth Science objectives
  - Need to assess anticipated performance, cost, and risk
  - Tradespace Analysis Tool for Constellations (TAT-C)
- The TAT-C knowledge base is a cumulative store of structured information about DSMs to inform analyses
- Prototype work on a KB for TAT-C demonstrates:
  - Storing/retrieving tradespace search requests
  - RESTful application programming interface (API)
  - Browser-based graphical user interface (GUI)

Future Work

- Develop formal DSM ontological models
  - Merge with existing knowledge bases, e.g. Wikidata
  - Import/link to unstructured data from other public sources
- Closer integration with specific TAT-C modules to dynamically adapt to new information availability
- Open platform to wider collaborative use:
  - Authentication and authorization
  - Data access control and version control
- Close design feedback loops with automation:
  - Build new search requests using existing object models
  - Find desirable architectures via inference on prior results

Thank you

Questions?

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