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

Paul T. Grogan[1], Philip Dabney[2], Olivier de Weck[3], Veronica Foreman[3], Sigfried Hache[1], Matthew Holland[2], Steven Hughes[2], Jacqueline Le Moigne[2], Sreeja Nag[2,4], Afreen Siddiqi[3]

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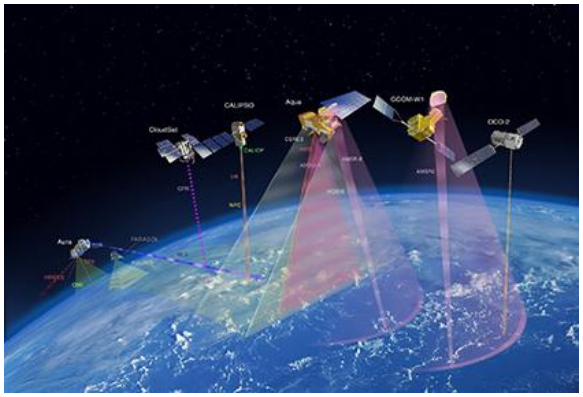
1. Stevens Institute of Technology, Hoboken NJ
2. Goddard Space Flight Center, Greenbelt MD
3. Massachusetts Institute of Technology, Cambridge MA
4. Bay Area Environmental Research Institute, Petaluma CA

NASA Earth Science Challenges

Landsat 8 (Source)

Traditional EO Mission:

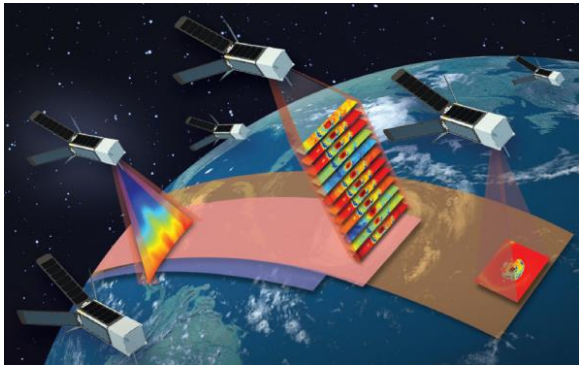
- Monolithic platform
- Direct value from collected data:
  - Operational Land Imager
  - Thermal Infrared Sensor



Afternoon Constellation (Source)

Novel EO "Mission":

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



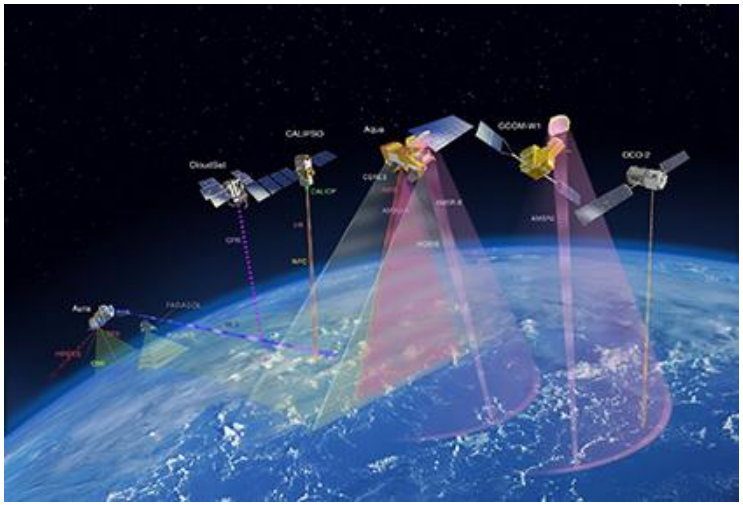
TROPICS (Source)

Future EO Mission:

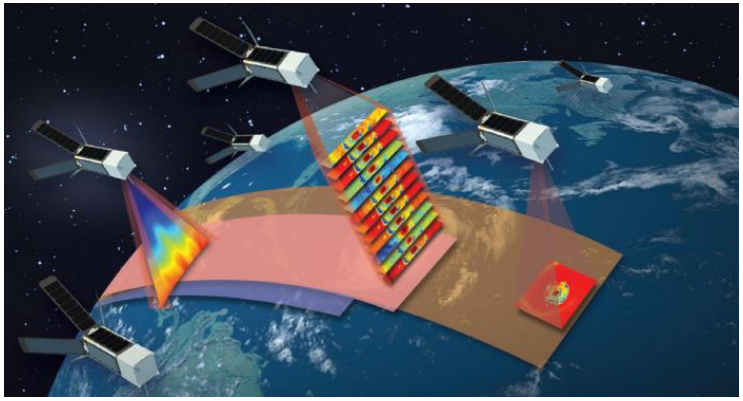
- Distributed platform
- Emergent value from composed data
  - Control member spacecraft

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)

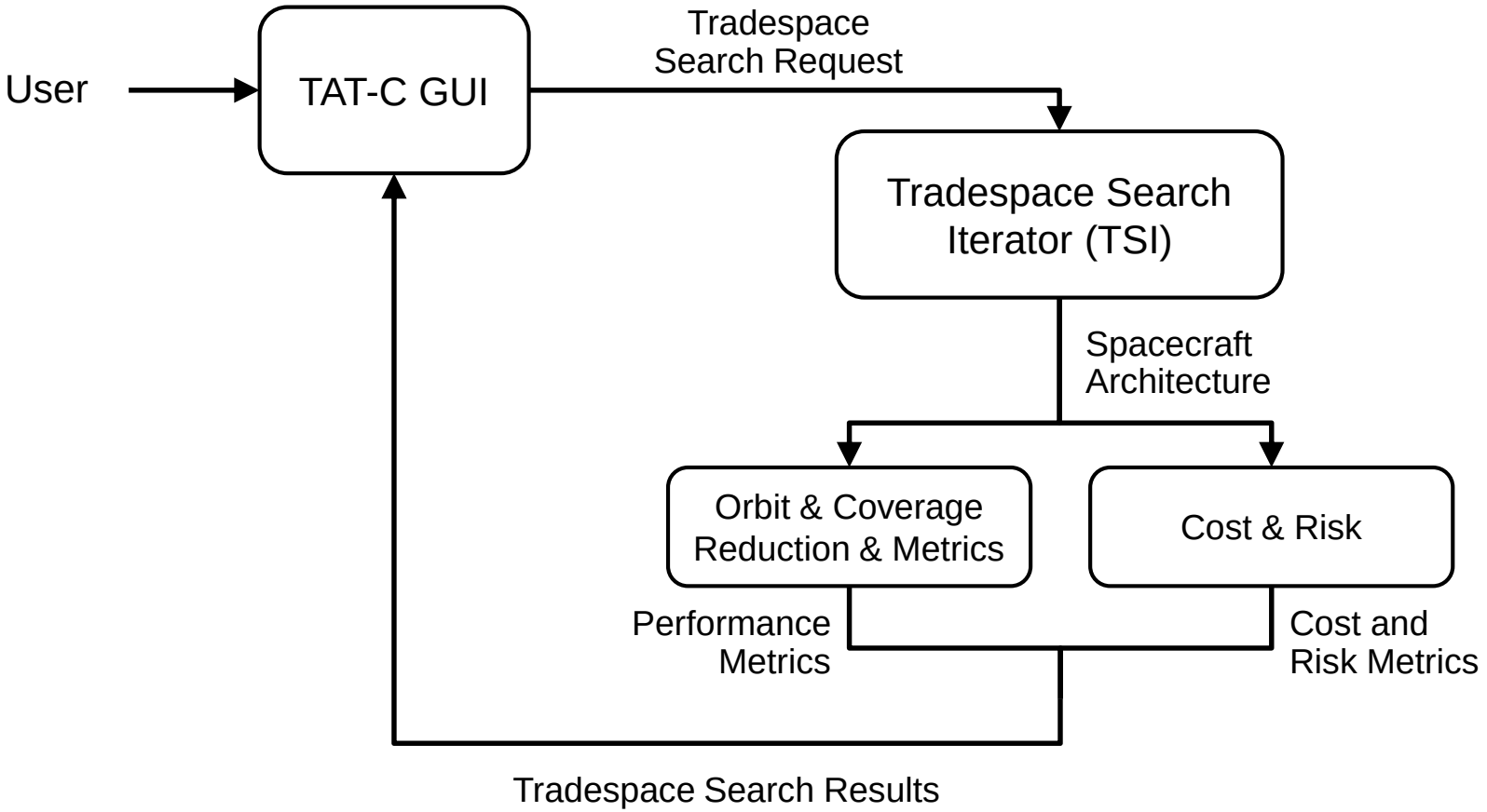


TROPICS Mission Concept (Source)

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?**

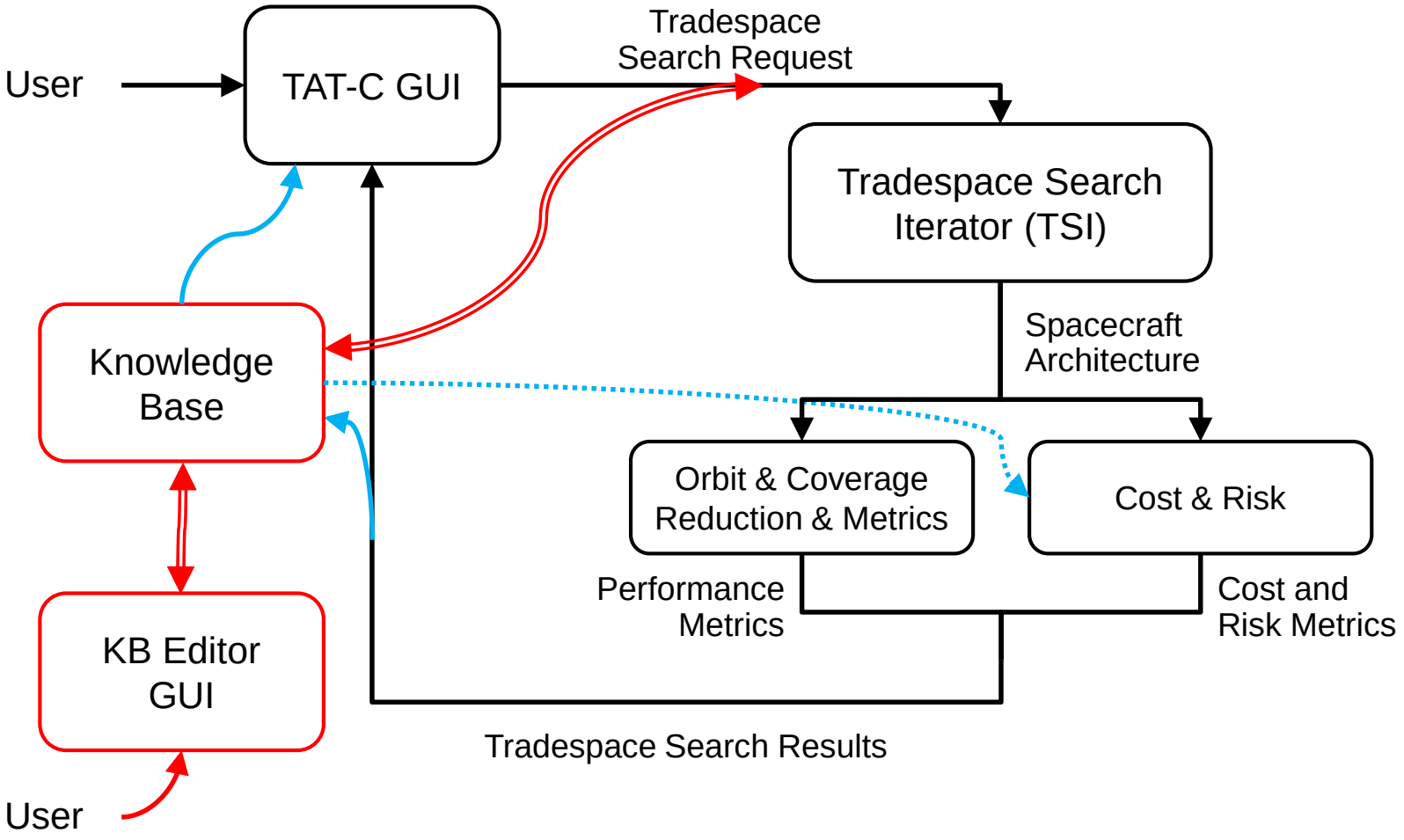
TAT-C Architecture



Knowledge Base

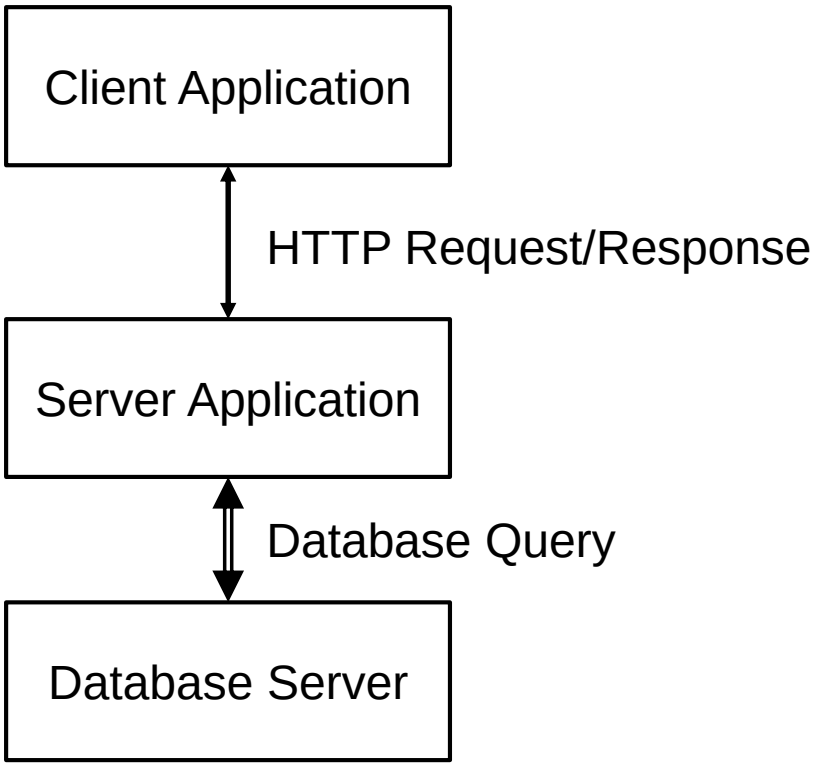
- Cumulative, common repository of information and meta-information about DSMs
  - Knowledge representation goes beyond data structure and syntax to also incorporate semantics and meaning
  - Loosely coupled with TAT-C, generally applicable to DSMs
- Preliminary services and features:
  - Store and retrieve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

TAT-C Architecture with KB

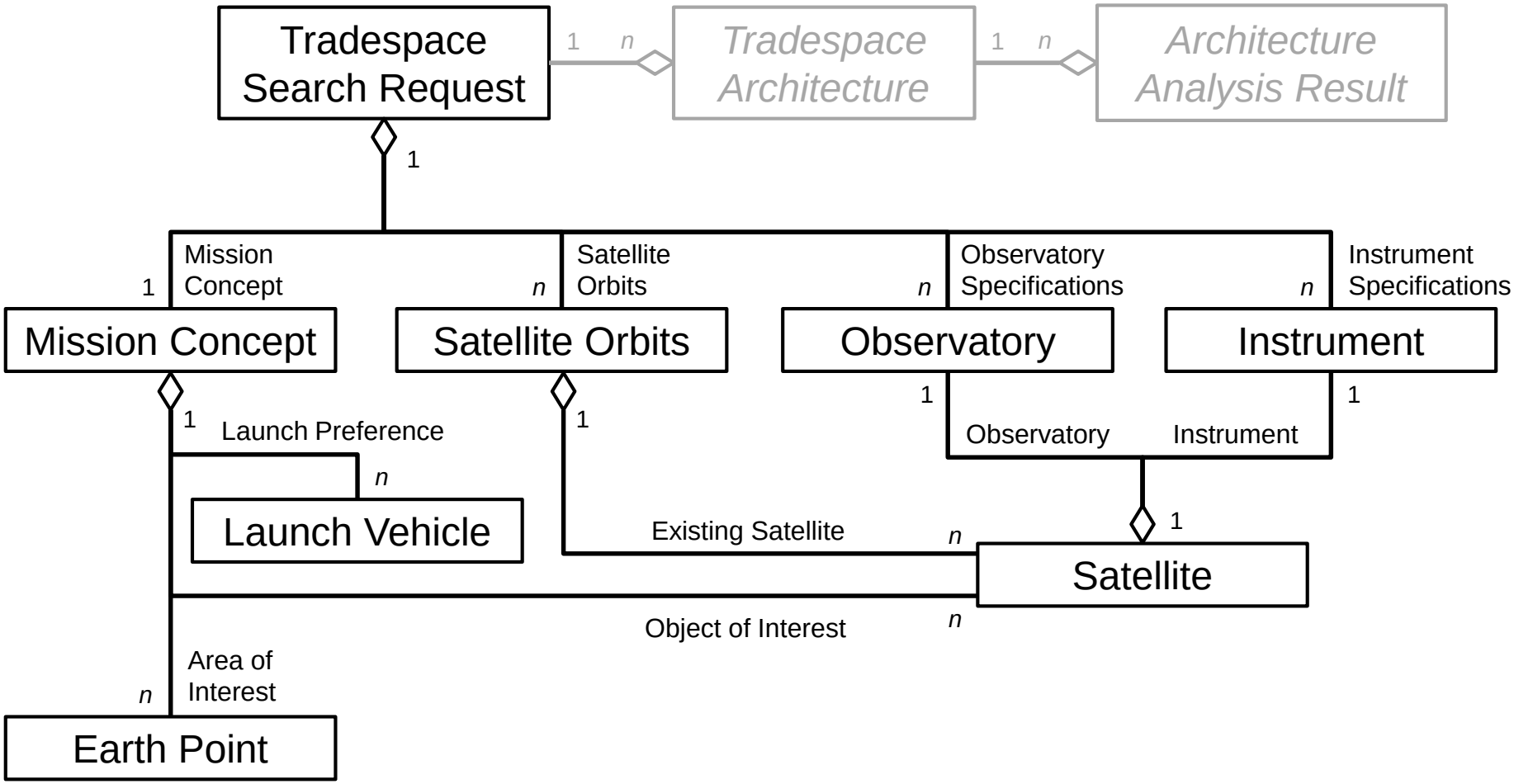


Knowledge Base Architecture

- 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

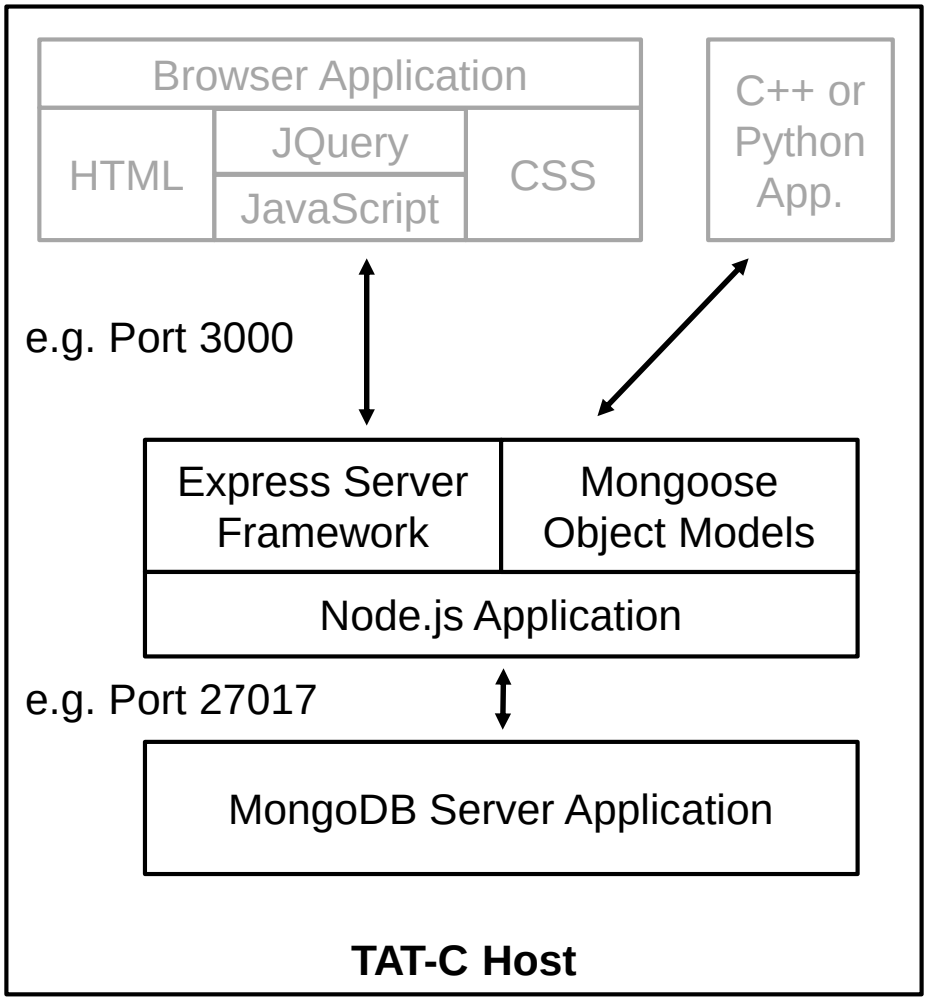
KB JSON Format

```
==============
{
  "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 format
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"]
}
```

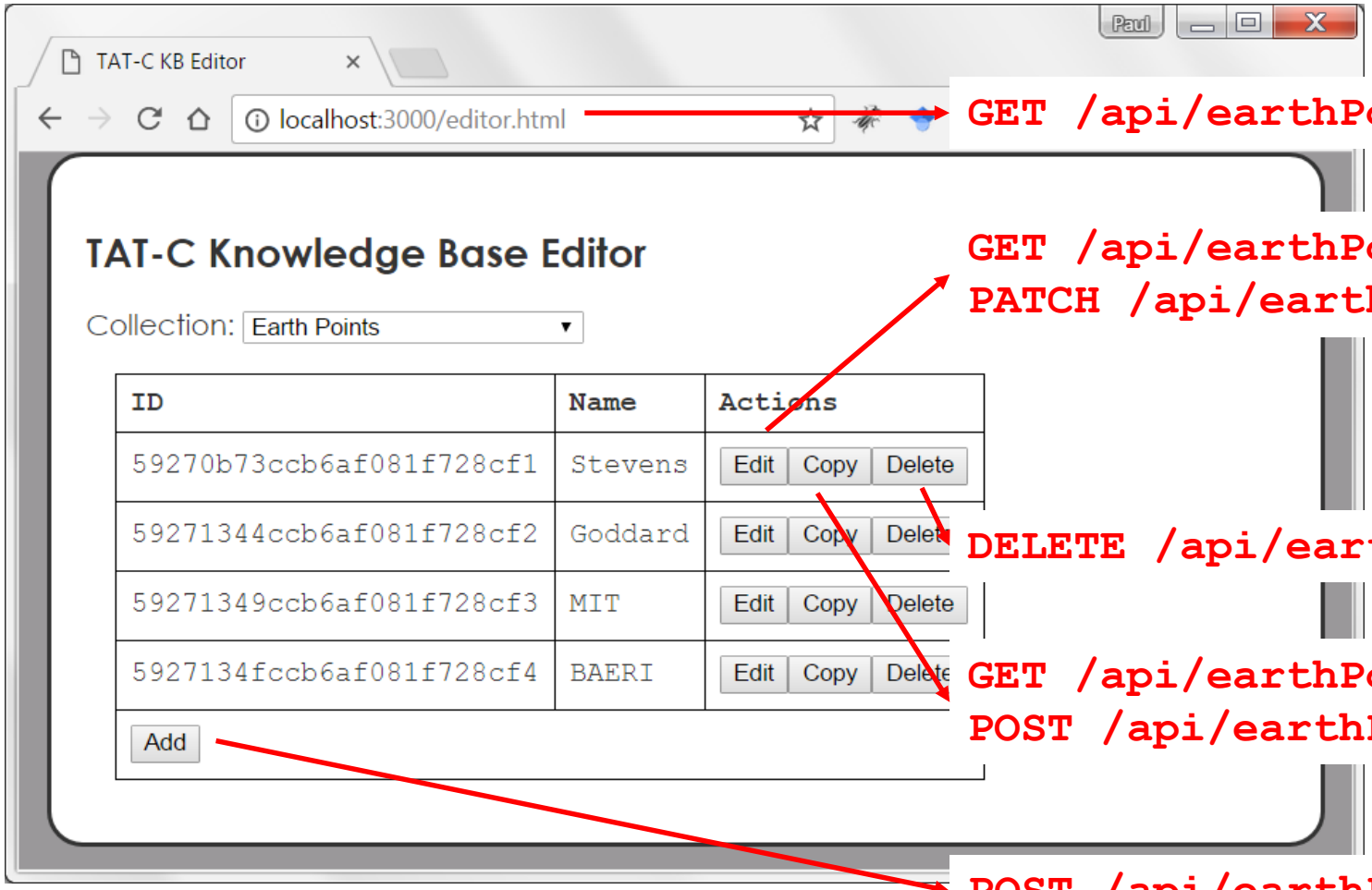
- Request:

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

- Response:

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

Prototype KB Editor



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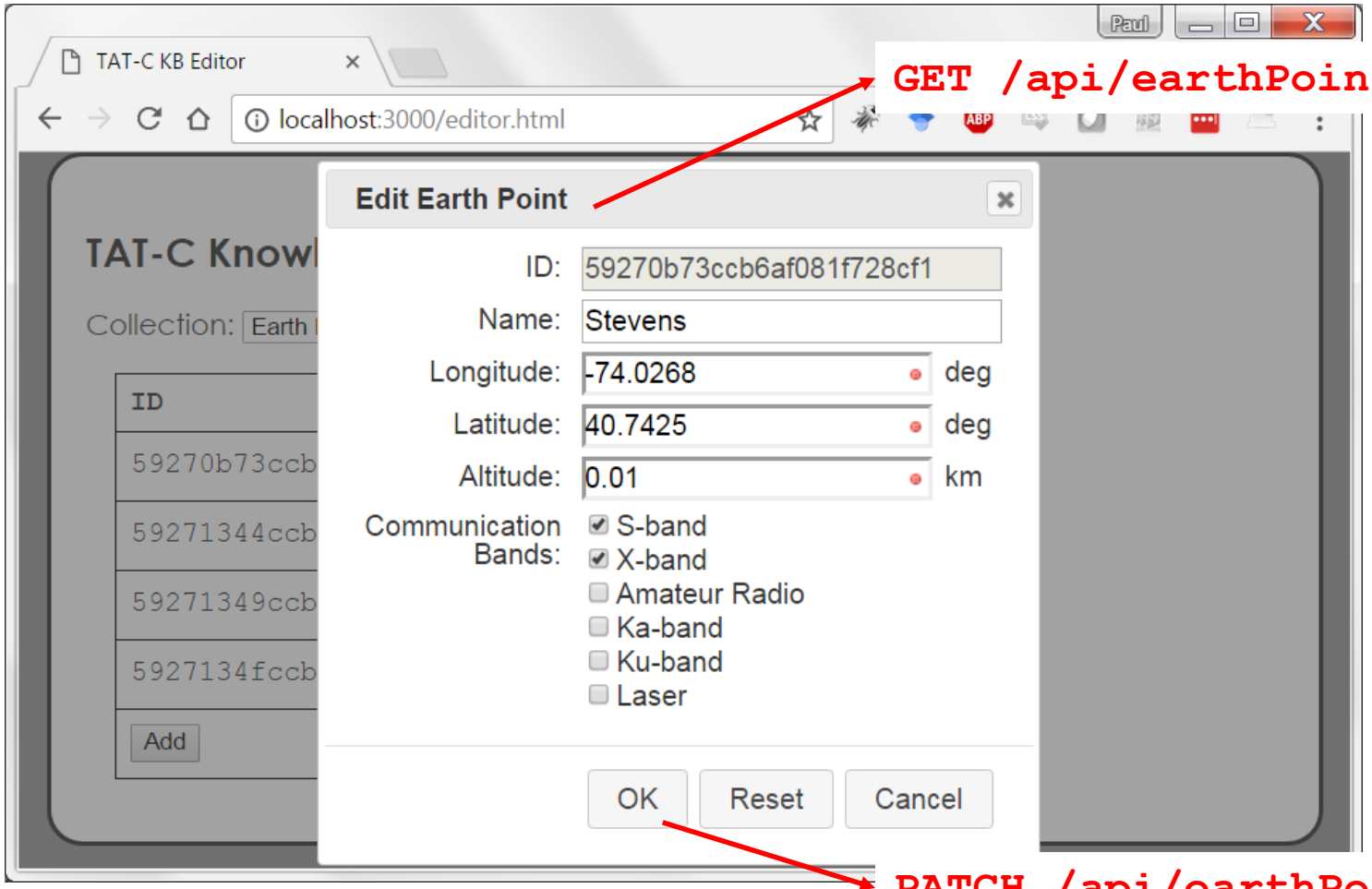

Summary

- 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?

Paul T. Grogan

pgrogan@stevens.edu