Authoritative Source of Truth (ASOT) to Analysis Using Huddle

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March 2021

Approved for public release. OTR 2021-00298.

Outline

- Digital Engineering and Authoritative Source of Truth (ASOT)

- Project Huddle
  - *Syntax and Semantic Translation*
  - *Huddle Portal*

- Case Study
  - *Ground Stations for ACME Corporation*
  - *Lessons Learned*

- Lessons Learned and Next Steps

DoD Digital Engineering (DE) & ASOT

DoD Digital Engineering Strategy, June 2018

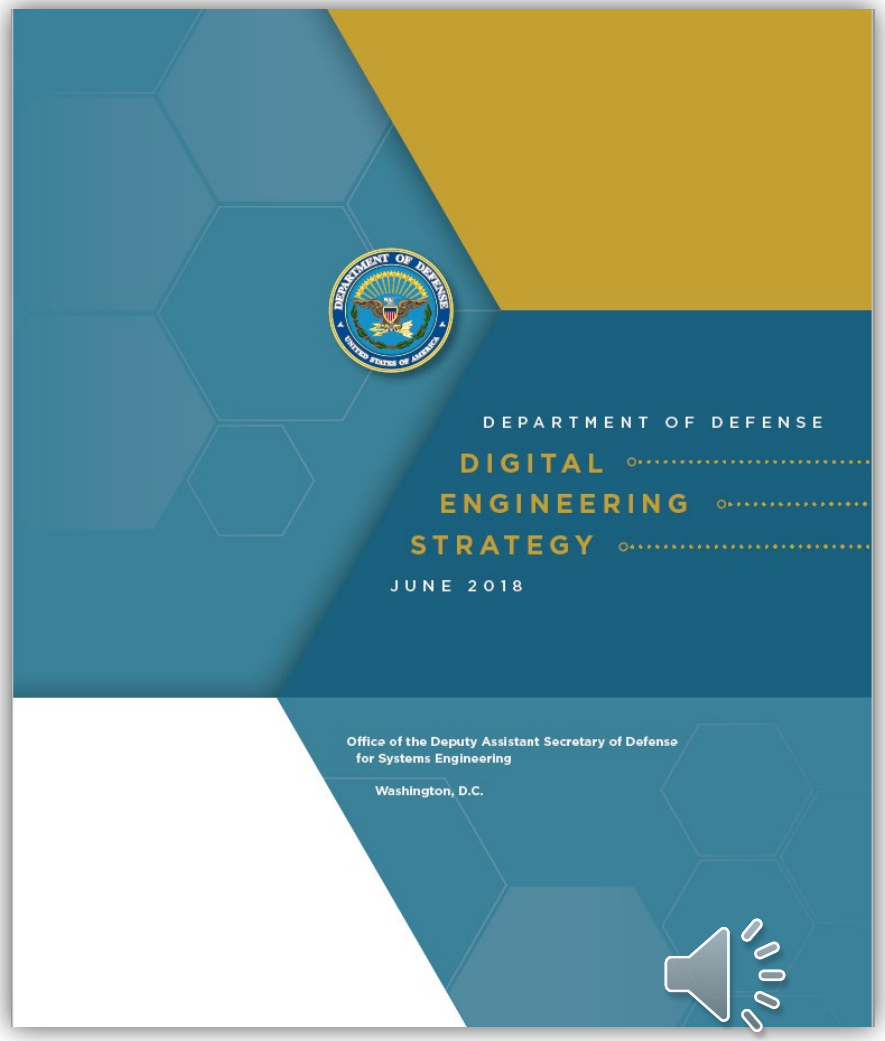
- "DoD defines digital engineering as an **integrated digital approach** that uses **authoritative sources of system data and models** as a continuum across disciplines to **support lifecycle activities from concept through disposal**."

- Various Authoritative Sources of Truth (ASOT) are being developed by the Space Force
  - *DoD Space Enterprise Model*
  - *SMC Portfolio Architecture (SPA) Model*
  - *Space Operations Enterprise Architecture (SOEA) Model*

- Different ASOTs can have information about the same system, and they each have their own metamodel

- An ASOT could be any number of things, such as a SysML model, spreadsheet, or custom database

- Mechanisms are needed to read the data from the ASOTs, transform the data, and feed it into analysis tools



Source: https://ac.cto.mil/wp-content/uploads/2019/06/2018-Digital-Engineering-Strategy_Approved_PrintVersion.pdf

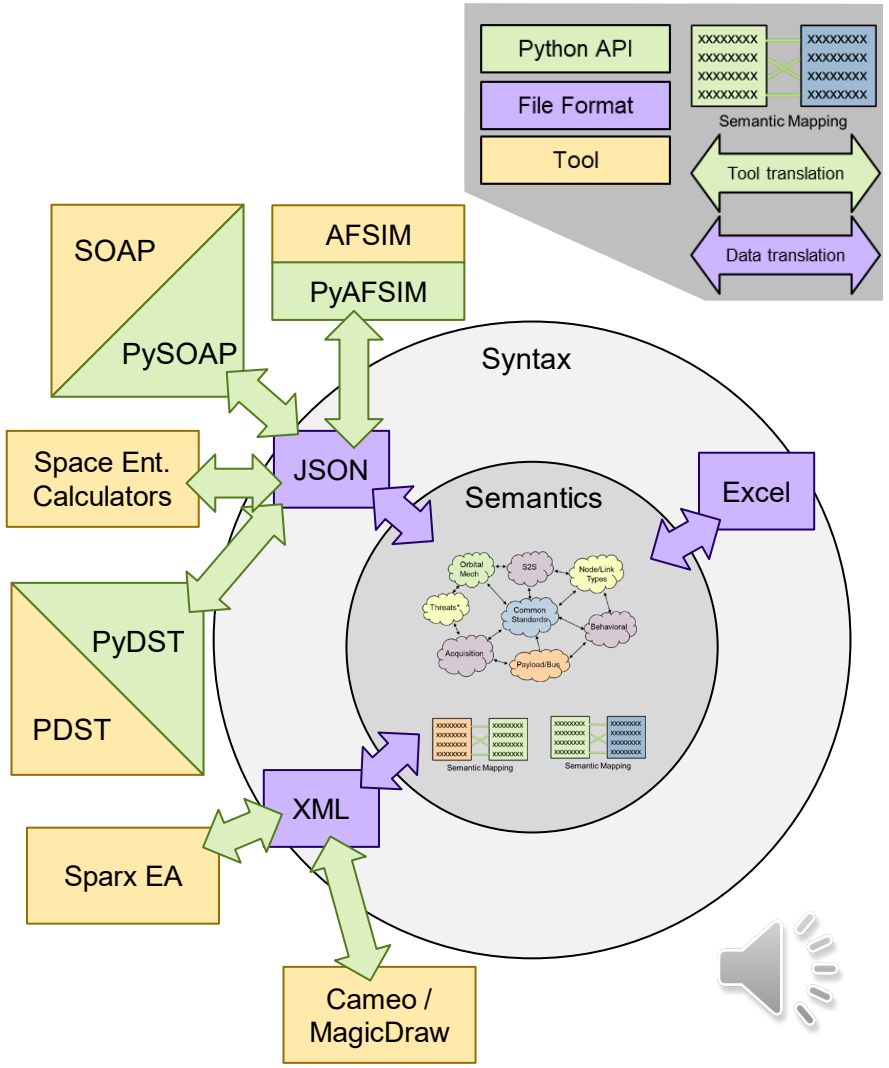
Project Huddle

Hub-and-Spoke Approach to Data Transformation

- **Project Goal:** Reduce overhead in data logistics
  - *Make it easy for analysts to get the data they need in the way they want it*
  - *Make it easy to share and update models*

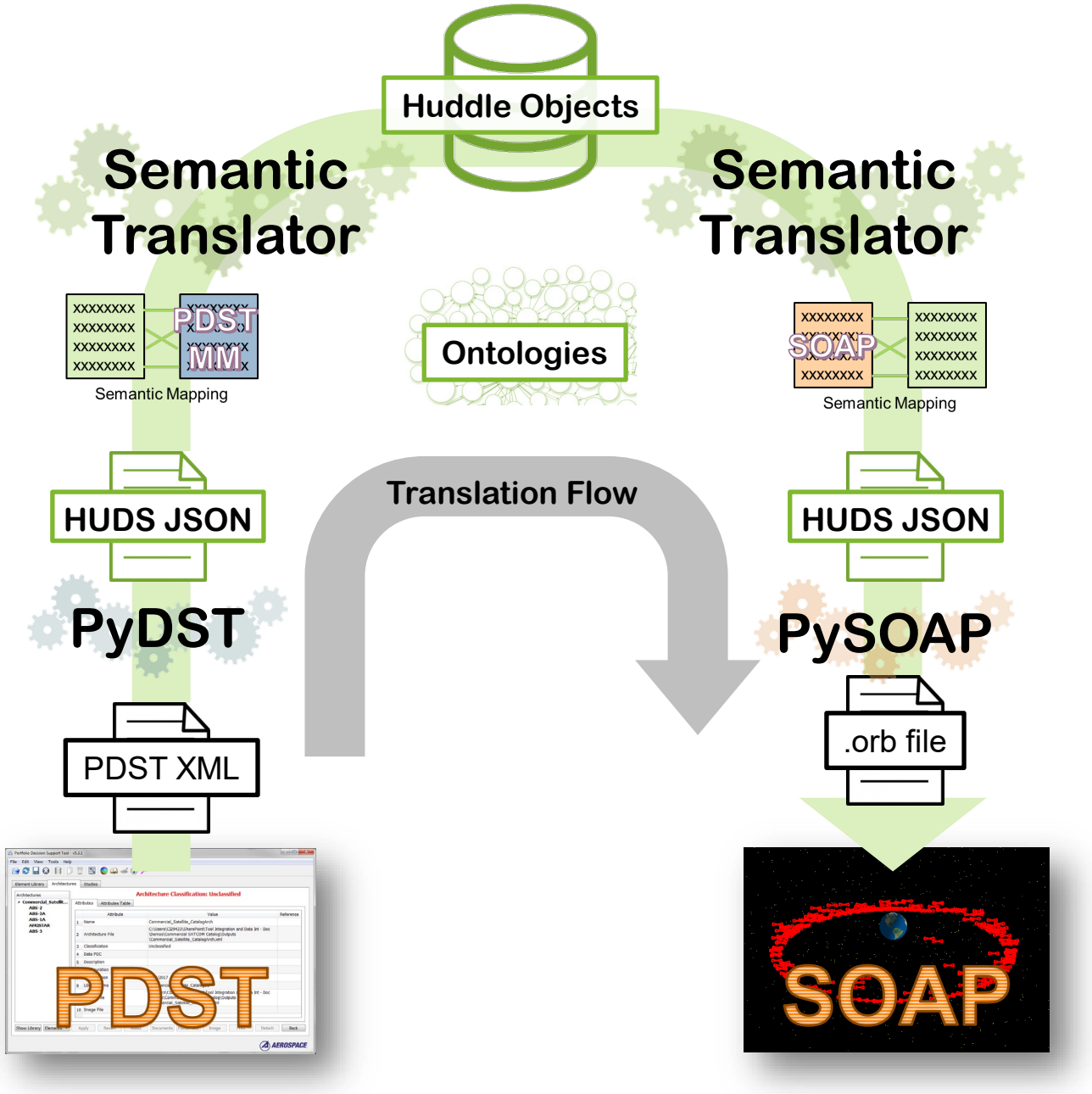
- **Implementation Approach**
  - *Ontologies that capture space analysis domains (e.g., space systems, orbital mechanics)*
  - *Software infrastructure that creates, stores, and updates data that conforms to this standard*
  - *Develop tools to read/write supported syntax (e.g., JSON, XML) and semantics (e.g., ontologies and metamodels)*
  - *Curated datasets and ASOTs (Authoritative Sources of Truth) on a website*

- **Current Capabilities**
  - *Website and REST APIs for users to upload, download, explore, and share models*
  - *Plugins for Sparx EA and Cameo to import and export SysML models that conform with our schema*
  - *Mappings between tools (see right for examples)*



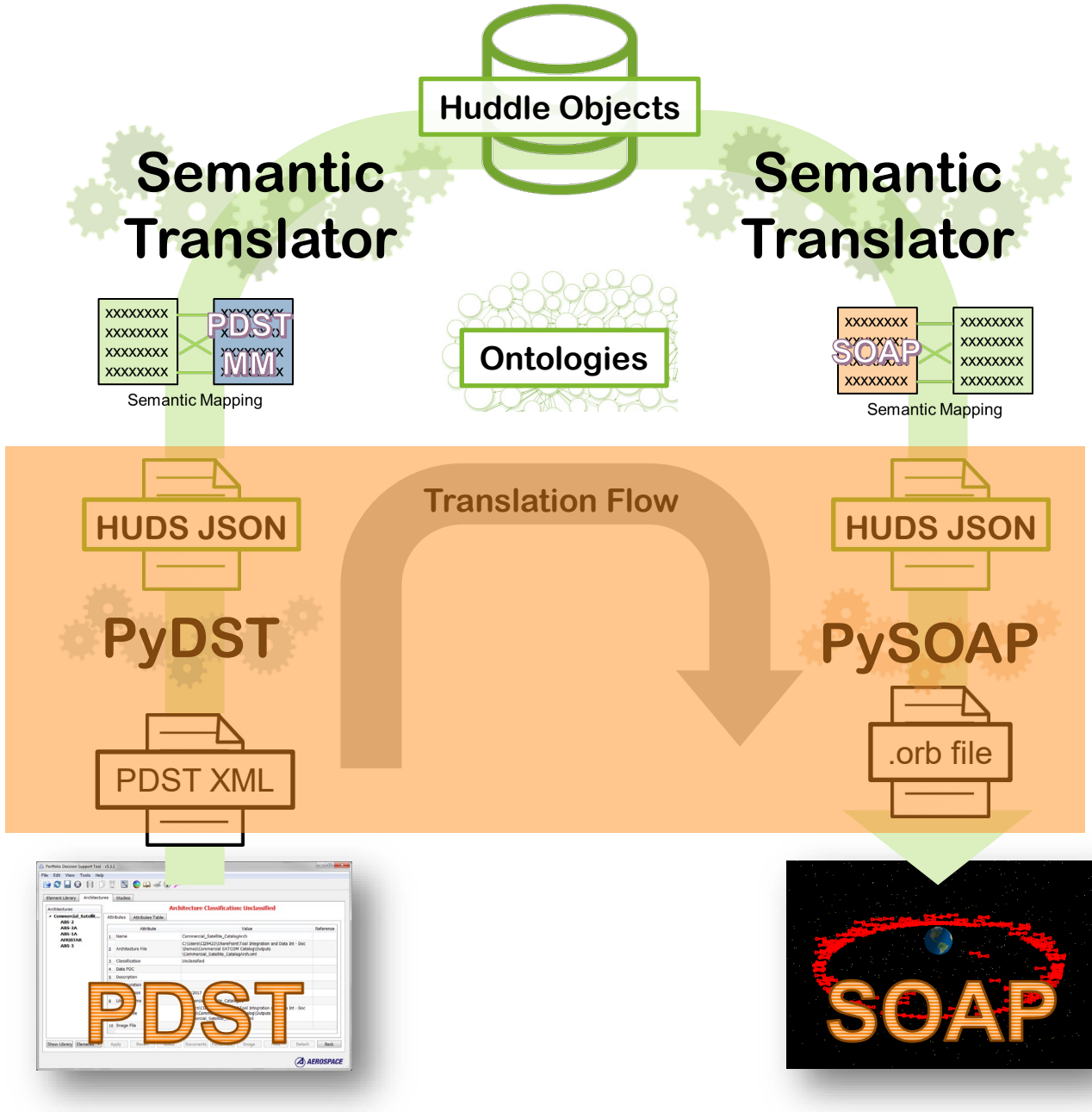
Huddle "Onion" Model

Translation Flow from PDST to SOAP



1. PDST saves its model as a PDST XML
2. PyDST converts the PDST XML into the Huddle JSON format
3. A semantic map transforms the data from PDST's metamodel to the Huddle ontologies and saves to the Huddle database
4. A SOAP semantic map transforms the loaded data from the Huddle ontologies to SOAP's metamodel
5. PySOAP converts the data from the Huddle JSON into SOAP's ORB file format

Translation Flow from PDST to SOAP



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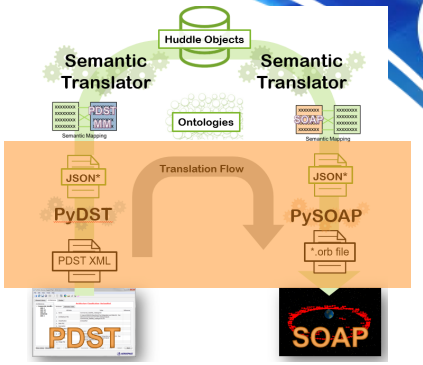
PDST Syntactic Translation

The syntactic translation focuses only on the data structure. It understands *how* specific objects, attributes of those objects and relationships between those objects are saved, and translates them to a common format.



Excerpts from PDST's XML

```
<Element id="PNT31134" type="Satellite" enabled="">
    <OpsGroups>GPS-IIRM</OpsGroups>
    <OpsActivationStates>Operations</OpsActivationStates>
    <Orbits>
        <Orbit id="PNT_GPS_SLOT_A2"/>
    </Orbits>
</Element>
```

```
<Satellite id="PNT31134" name="GPS-IIR-15 (M2)">
    <Description>NAVSTAR Global Positioning System Block IIR - SV-15</Description>
    <AcquisitionAgency>SMC/GP</AcquisitionAgency>
    <PrimeContractor>Lockheed Martin</PrimeContractor>
    <CustomAttributes>
        <Attribute name="Design Life (yrs)">7.5</Attribute>
    </CustomAttributes>
    <OVlIcon>images/icons/gps.png</OVlIcon>
</Satellite>
```

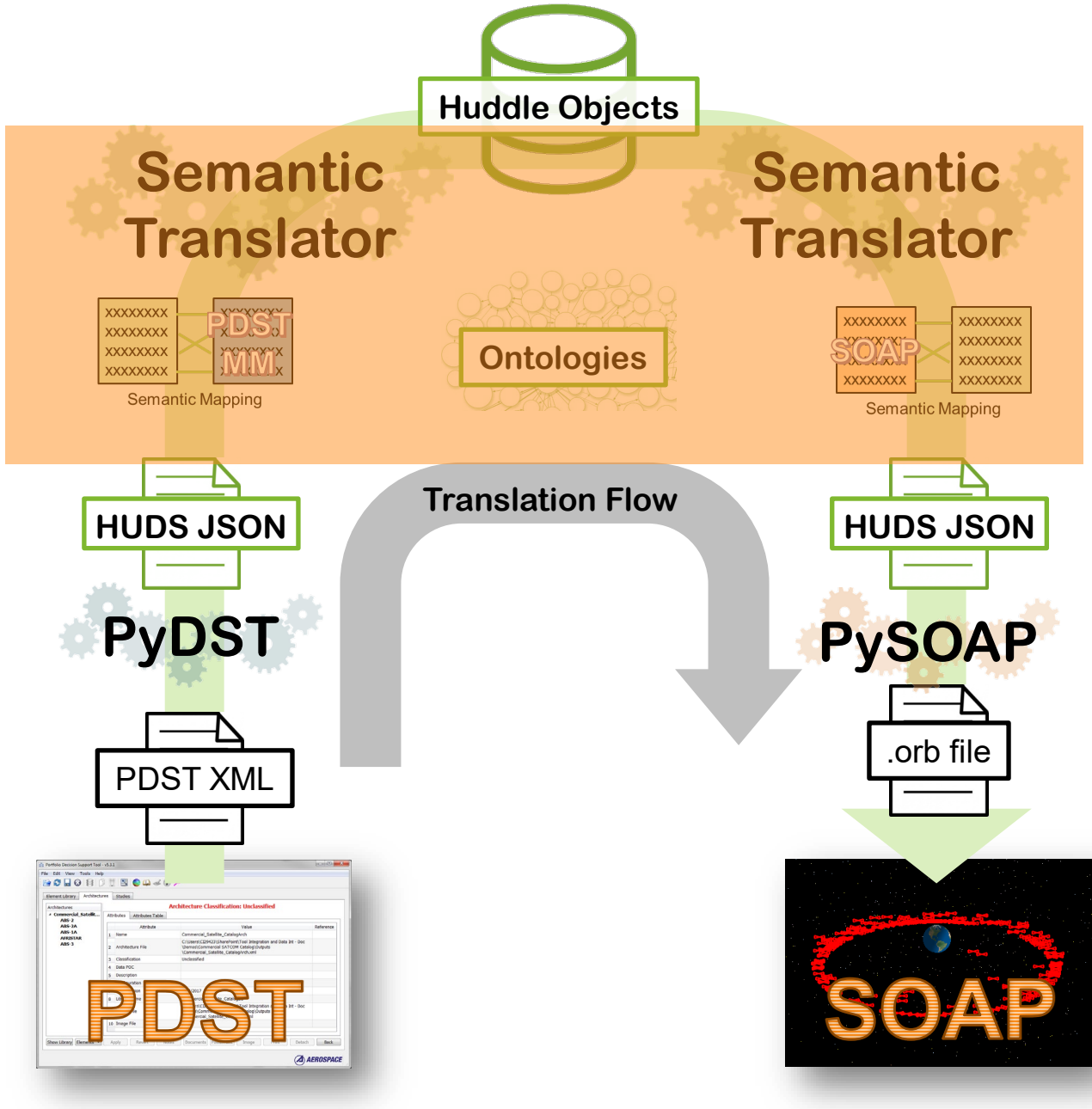
```
<Orbit id="PNT_GPS_SLOT_A2" name="GPS Slot A2" type="MEO" slot="GPS Slot A2">
    <Description>GPS Medium Earth Orbit - 12 hr period, repeating ground track,
    <OrbitAltitude units="km">20368</OrbitAltitude>
    <SemiMajorAxis units="km">26559.7999999999</SemiMajorAxis>
    <Eccentricity>4.6111025347562E-16</Eccentricity>
    <Inclination>54.9999999999999</Inclination>
    <RAAN>296.23</RAAN>
    <ArgPerigee>0</ArgPerigee>
    <MeanAnomaly>292.61</MeanAnomaly>
</Orbit>
```

Excerpts from HUDS JSON

```
{
  "type": "pdst.Satellite",
  "id": {
    "pdst": "PNT31134"
  },
  "attributes": {
    "library": "PNT Library",
    "name": "GPS-IIR-15 (M2)",
    "Description": "NAVSTAR Global Positioning System Block IIR - SV-15",
    "AcquisitionAgency": "SMC/GP",
    "PrimeContractor": "Lockheed Martin"
  },
  "relationships": {
    "Orbit": [
      {
        "id": "PNT_GPS_SLOT_A2",
        "type": "pdst.Orbit"
      }
    ],
  }
},
```

```
{
  "type": "pdst.Orbit",
  "id": {
    "pdst": "PNT_GPS_SLOT_A2"
  },
  "attributes": {
    "library": "PNT Library",
    "name": "GPS Slot A2",
    "type": "MEO",
    "slot": "GPS Slot A2",
    "Description": "GPS Medium Earth Orbit - 12 hr period, repeating ground track,
    "OrbitAltitude": "20368",
    "SemiMajorAxis": "26559.7999999999",
    "Eccentricity": "4.6111025347562E-16",
    "Inclination": "54.9999999999999",
    "RAAN": "296.23",
    "ArgPerigee": "0",
    "MeanAnomaly": "292.61"
  }
},
```

Translation Flow from PDST to SOAP



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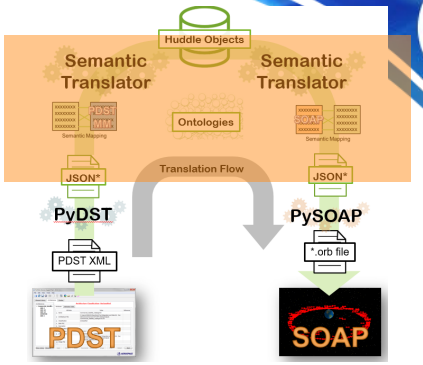
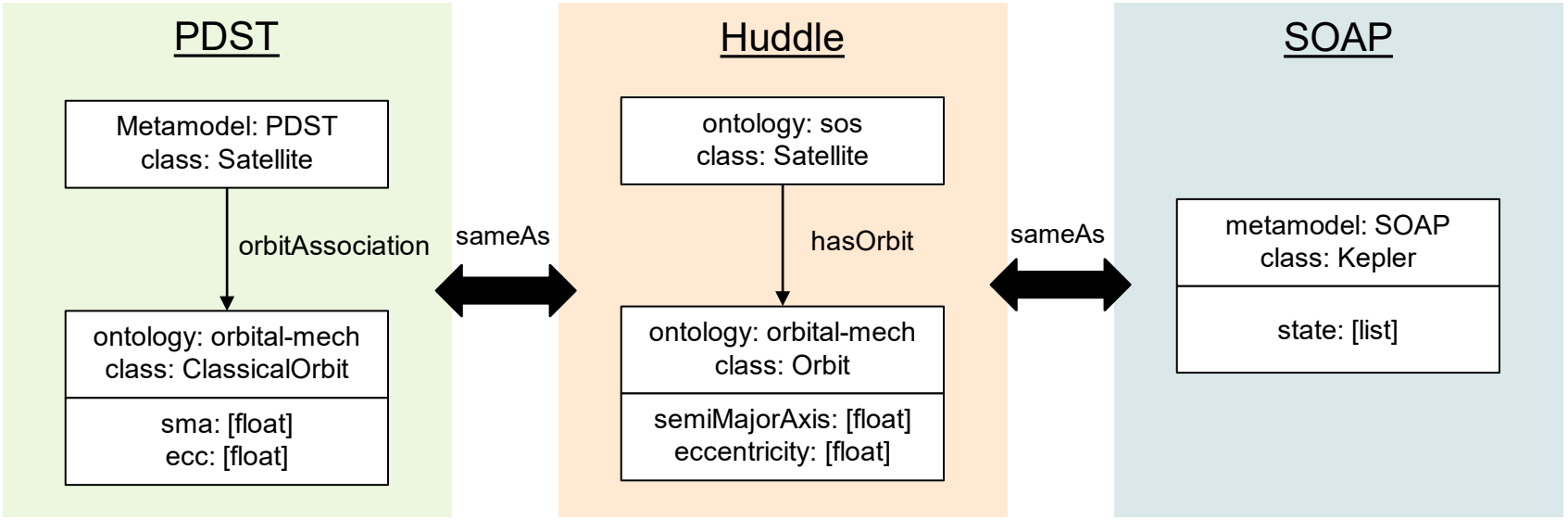
Example Semantic Mapping

The semantic translation focuses on the vocabulary used. It maps concepts from a tool metamodel to the ontologies and translates the language to either map to the common ontologies or explicitly remain in the tool's metamodel.

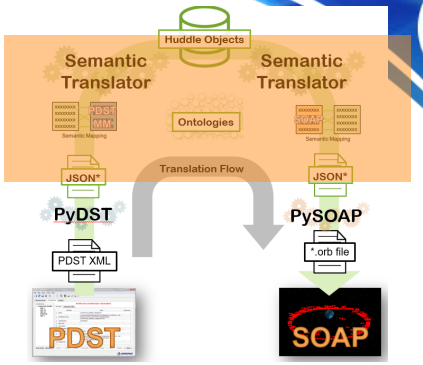




Type	Ontology	Huddle Equivalent	PyDST Equivalent	PySOAP Equivalent
Class	sos	Satellite	Satellite	Kepler
Class	orbital-mech	Orbit	Orbit	
Attribute	orbital-mech	Orbit.semiMajorAxis	Orbit.sma	Kepler.state[0]
Relationship	sos –> orbital-mech	Satellite – hasOrbit –> Orbit	Satellite – orbitAssociation –> Orbit	

PDST Semantic Translation

The semantic translation focuses on the vocabulary used. It maps concepts from a tool metamodel to the ontologies, and translates the language to either map to the common ontologies or explicitly remain in the tool's metamodel.



PDST Semantics

Translated from PDST to SOS

```
{
  "type": "pdst.Satellite",
  "id": {
    "pdst": "PNT31134"
  },
  "attributes": {
    "pdst_type": "pdst.Satellite",
    "name": "GPS-IIR-15 (M2)",
    "description": "NAVSTAR Global Positioning System Block IIR -
    SV-15",
    "acquisition_agency": "SMC/GP",
    "prime_contractor": "Lockheed Martin",
  },
  "relationships": {
    "orbits": [
      {
        "type": "pdst.Orbit",
        "id": "576bc00958914d07a18eb70e1bfbae25"
      }
    ]
  }
},
{
  "type": "pdst.Orbit",
  "id": {
    "pdst": "PNT_GPS_SLOT_A2",
    "huddle": "576bc00958914d07a18eb70e1bfbae25"
  },
  "attributes": {
    "name": "GPSPlaneASlot2",
    "alt": 20368.0,
    "epoch": "1991-12-01T00:00:00",
    "description": "GPS Medium Earth Orbit - 12 hr period,
    repeating ground track, inclined 55 deg.  Slot A2",
    "slot": "GPS Slot A2",
    "sma": 26559.7999999999,
    "ecc": 4.6111025347562e-16,
    "inc": 54.9999999999999,
    "raan": 296.23,
    "argperi": 0.0,
    "meananom": 292.61
  },
```

Huddle-ontology Semantics

```
{
  "type": "sos.Satellite",
  "id": {
    "pdst": "PNT31134",
    "huddle": "0f012dbd67e74c1cbde622ef2877ea99"
  },
  "attributes": {
    "pdst_type": "pdst.Satellite",
    "name": "GPS-IIR-15 (M2)",
    "description": "NAVSTAR Global Positioning System Block IIR
    - SV-15",
    "acquisition_agency": "SMC/GP",
    "prime_contractor": "Lockheed Martin"
  },
  "relationships": {
    "hasOrbit": [
      {
        "type": "orbital.Orbit",
        "id": "576bc00958914d07a18eb70e1bfbae25"
      }
    ]
  }
}
{
  "type": "orbital.Orbit",
  "id": {
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    "huddle": "576bc00958914d07a18eb70e1bfbae25"
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  "attributes": {
    "name": "GPSPlaneASlot2",
    "alt": 20368.0,
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    "description": "GPS Medium Earth Orbit - 12 hr period,
    repeating ground track, inclined 55 deg.  Slot A2",
    "slot": "GPS Slot A2",
    "semiMajorAxis": 26559.7999999999,
    "eccentricity": 4.6111025347562e-16,
    "inclination": 54.9999999999999,
    "rightAscensionOfAscendingNode": 296.23,
    "argumentOfPerigee": 0.0,
    "meanAnomaly": 292.61
  },
```
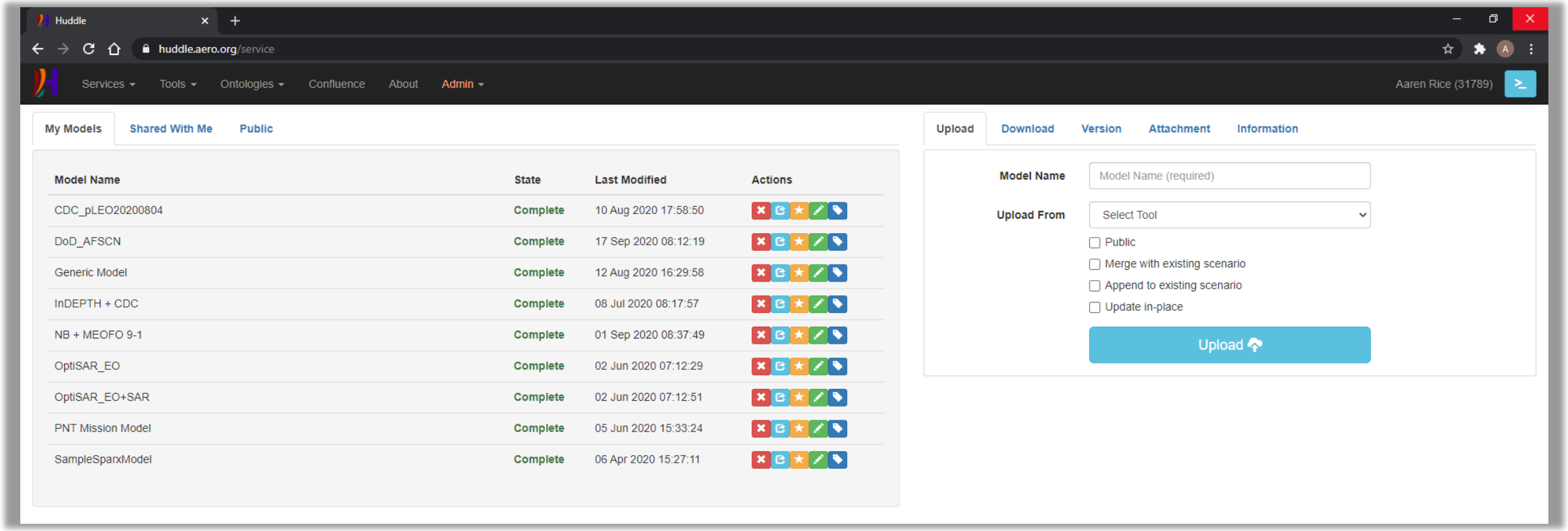

Huddle Portal



- Capabilities
  - *Upload, merge, and append models to the web, with the ability to share with others*
  - *Download models in different formats and filter based on data object type (e.g., Satellites, Ground Stations), PDST capability, and time*

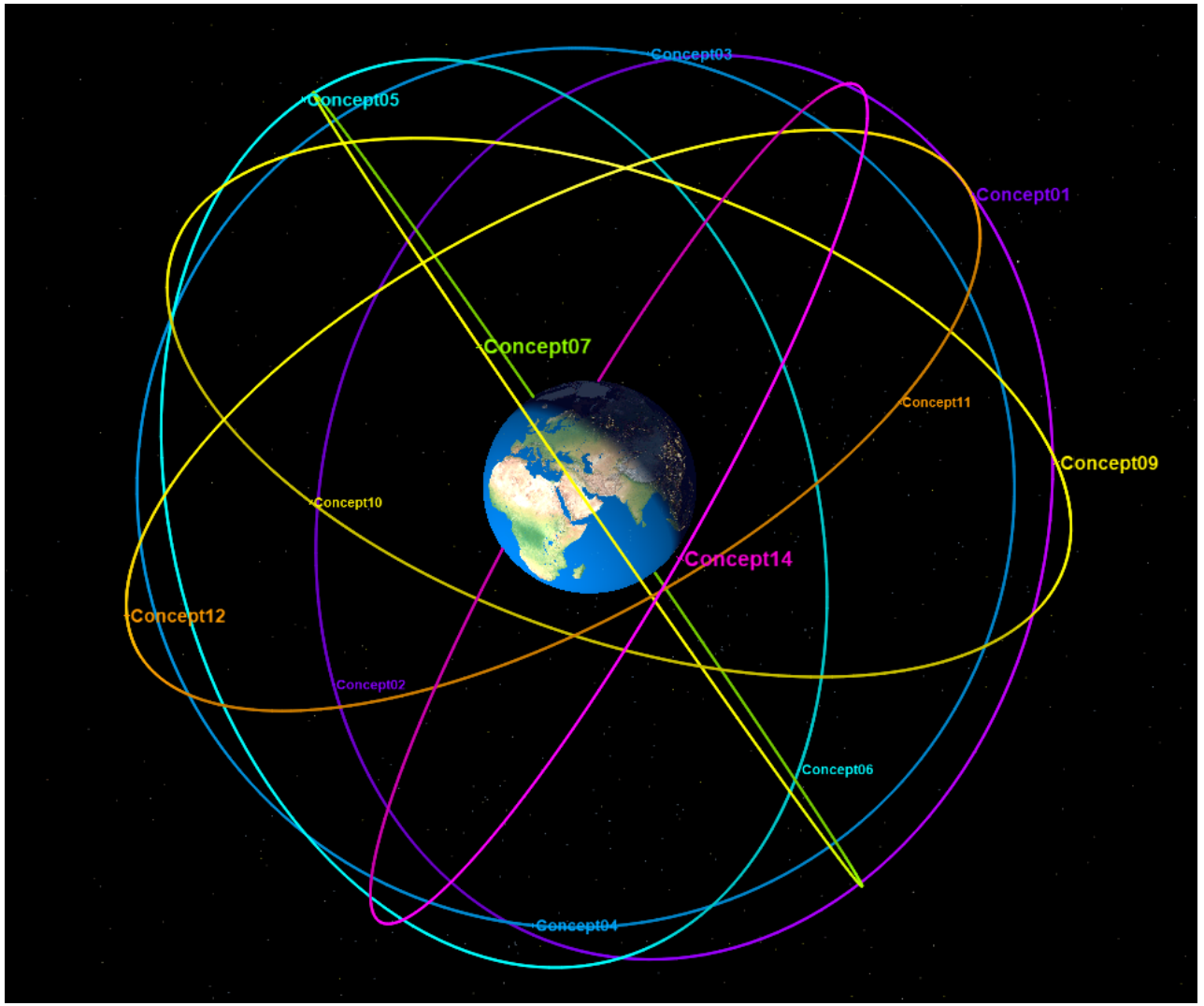
Case Study

The fictional ACME Corporation needs a set of ground stations to support their new satellite constellation.

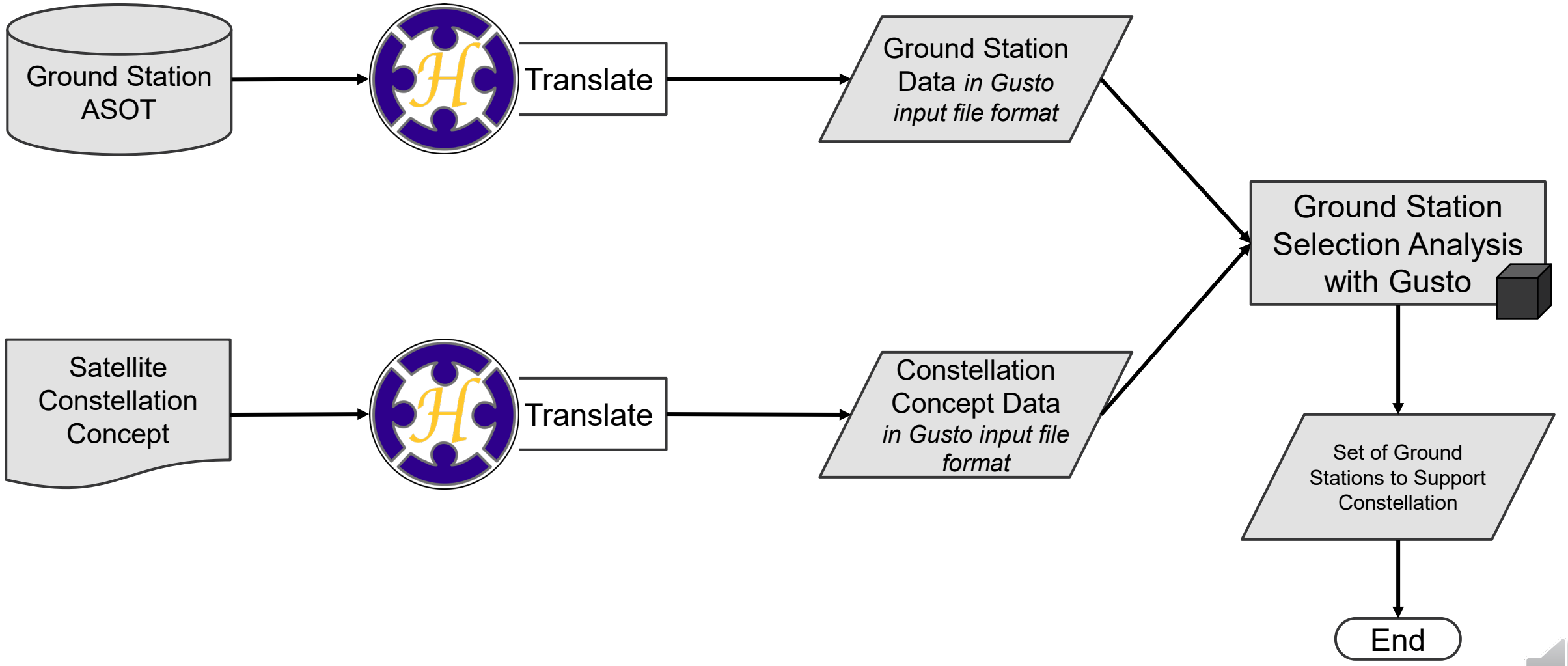
Huddle enables the quick and easy translation of ASOT and concept data for use in analysis tools.

Case Study: ACME Ground Services

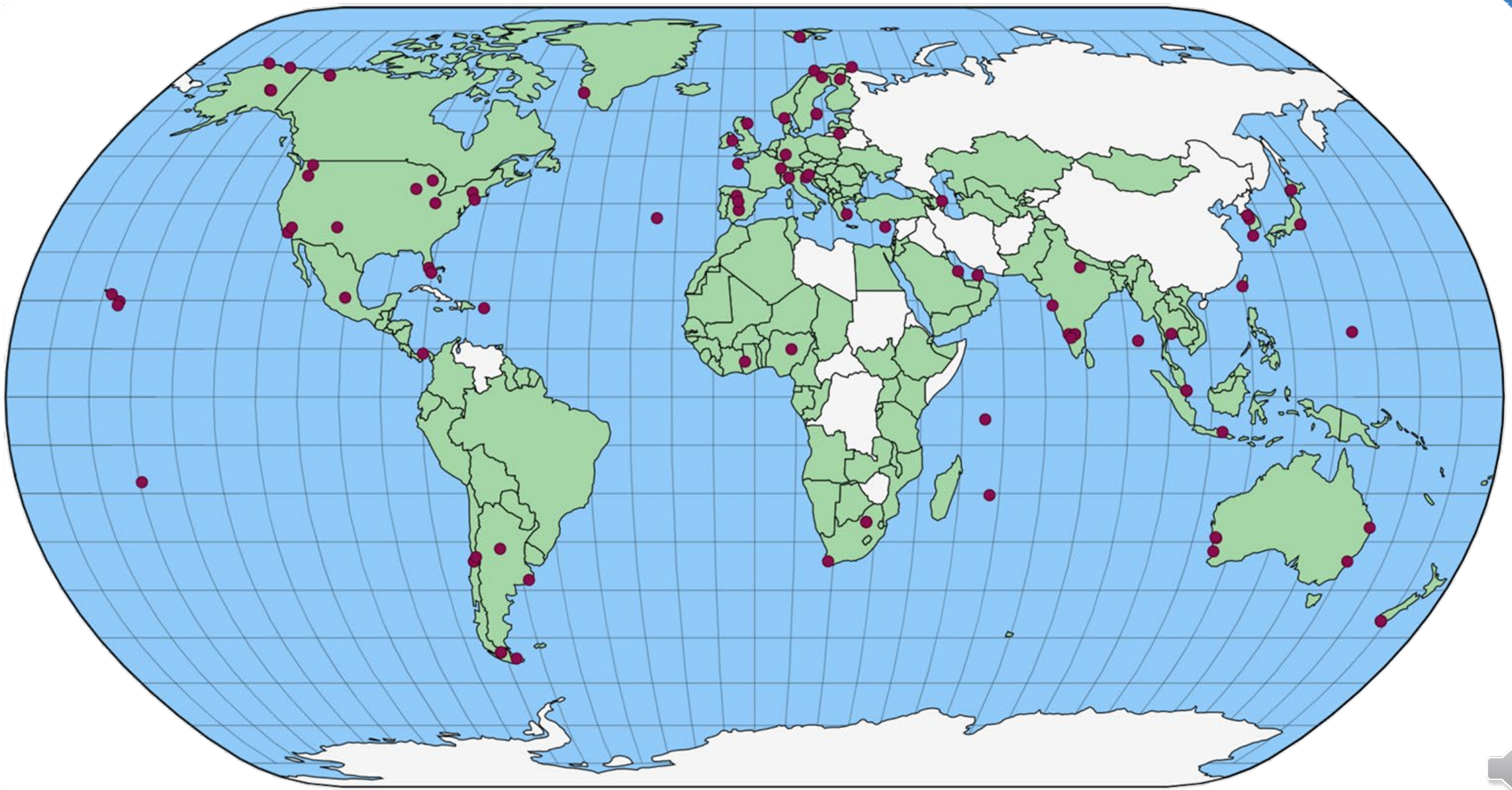
- The fictional ACME Corporation has a new satellite architecture concept
- Constellation parameters:
  - *20,000 km altitude*
  - *60 degree inclination*
  - *Walker TPF: 14/7/1*
- ACME needs a set of ground stations to support their satellites
- They want those satellites to always have at least one ground station in view
- But they don't want to build their own ground stations, so they decide to buy time on commercial antennas
- The Aerospace Corporation can use its commercial antenna ASOT database, Huddle, and a ground station selection tool, Gusto, to help ACME choose its ground stations



Analysis Overview

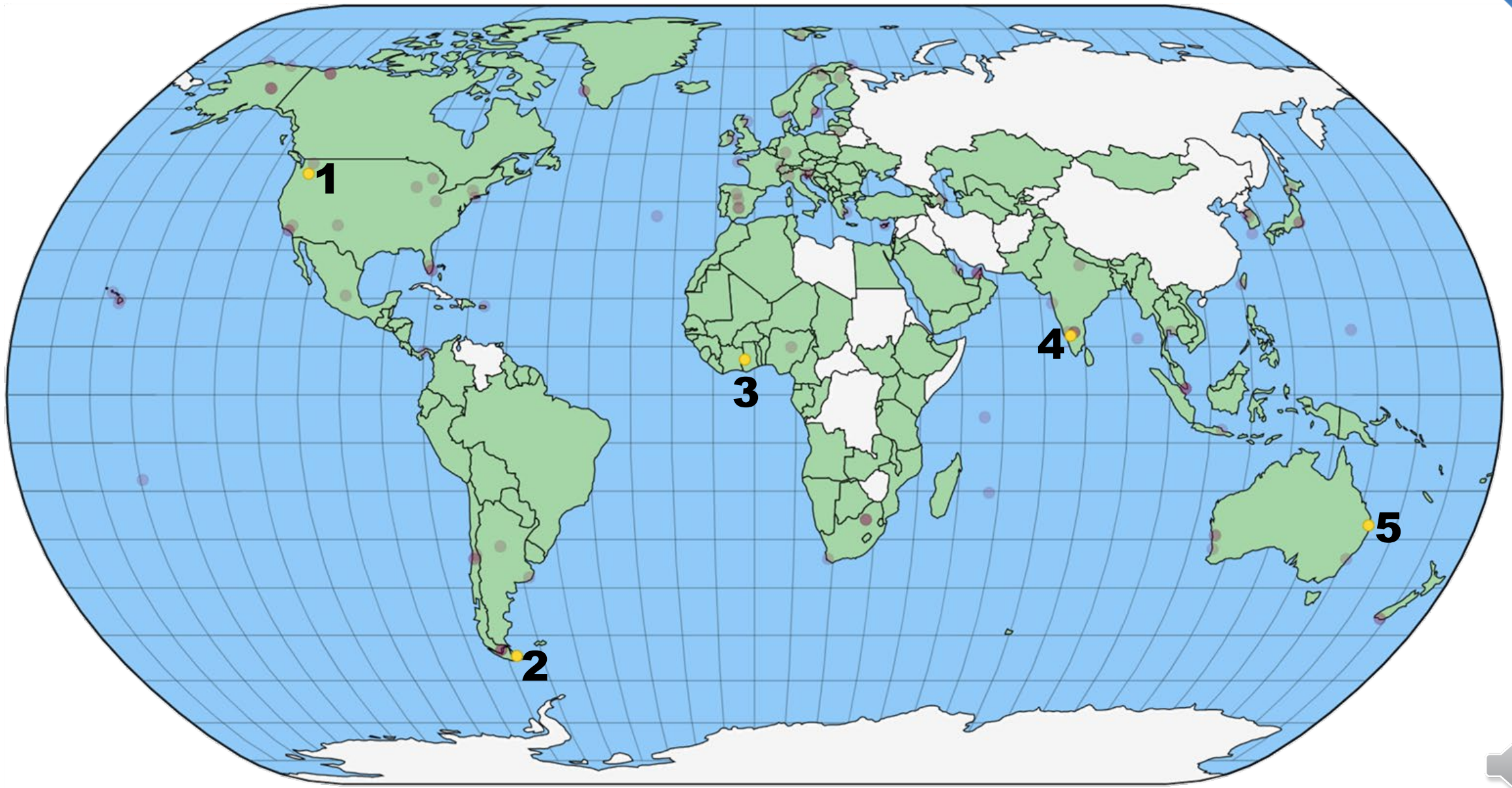


Considered Commercial Ground Stations



References: slide 21

One Possible Ground Station Set for Gapless Coverage



Lessons Learned

- Make existing tools more “web-enabled”
  - *Develop mechanisms for existing tools to pull data from web endpoints, and if appropriate, push data back*
  - *Develop new tools or versions of existing tools that are browser-based*

- Being consistent with the various data translation layers
  - *Hitting a moving target is difficult*
  - *That consistency is key to meaningful data transformation*

Next Steps and Future Path

- Automation of Analyses
  - *Analyses can be set up and run as background routines on a daily, as-needed, or upon-change basis*
  - *Building a user-friendly automation interface will allow users to customize analyses from ASOTs*
    - Similar to business process or email automation

- Managing Architecture Alternatives
  - *With the baselines captured and shared with DE tools, architectural alternatives can be created for tradeoffs*
  - *This presents challenges in managing the data, such as*
    - Maintaining traceability between alternatives while tracking the changes
    - Merging changes from branches to the baseline and vice versa

- Decision Support
  - *Develop robust and realistic schedules and budgets by plugging in optimization and Monte Carlo analysis capabilities*

Summary & Thank You

- DE Implementation is steadily progressing, and more ASOTs are becoming developed and matured
- Mechanisms to use the data in the ASOTs to feed analysis tools are needed
- Huddle Portal provides a convenient way for users to get access to the data in convenient formats
- The case study highlighted notional use of an ASOT ground station database and a satellite constellation concept to perform a ground gateway optimization study
- Automation of analyses using ASOTs can unlock greater efficiencies and new use cases in DE

References

Commercial Ground Station Location References

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