EO and SAR Constellation
Imagery Collection Planning

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Orbit Logic specializes in software for scheduling and situational awareness.

- Primary markets: aerospace and geospatial intelligence
- Off-the-shelf products, customized solutions, and services
- Create better plans faster with fewer resources and more insight for all mission phases
Course Outline

- Introduction to Collection Planning
- The Collection Planning Model
- Collection Planning Operations
Introduction to Collection Planning
What is Collection Planning

According to Wikipedia

“An intelligence collection plan (ICP) is the systematic process used by most modern armed forces and intelligence services to meet intelligence requirements through the tasking of all available resources to gather and provide pertinent information within a required time limit”

Our Definition

All the mission planning and scheduling required to generate a valid and optimized plan for collecting imagery using one or more imaging satellites
Collection Planning Lexicon

- **Target**
  - AOI = Area of interest

- **Order**
  - Request for Imagery = AOI + constraints

- **Fulfilment**
  - Image has been taken for all or part of an Order

- **Field of Regard**
  - Whole area the sensor can possibly observe at a point of time

- **Field of View**
  - Instantaneous footprint of the sensor

- **Agile**
  - Capable of pointing in any direction

- **SAR**
  - Synthetic Aperture Radar

- **EO**
  - Electro Optical
Satellite Imagery Collection Cycle

Order

Analyze

Plan

Process and Deliver

Downlink

Uplink

Image

Process and Deliver

Downlink

Uplink

Image

Analyze

Plan
Satellite Imagery Collection Cycle

Create better plans faster with fewer resources and more insight

Order Management System

Collection Planning System

GIS

Image Processing

Telemetry and Imagery Downlink

Imaging Satellite

Command System
The Collection Planning Challenge

- **Large Solution Space**
  - Thousands of imaging orders
  - Agile satellites/sensors

- **Performance to Support Many Planning Sessions**
  - Multiple orbits per day per spacecraft
  - Multiple spacecraft

- **Short Timelines**
  - Customer desire for fast order turn-around
  - Dynamic cloud forecasts

- **Desire for “Optimized” Plans**
  - Maximize return from limited and expensive resources
  - Balance Priority, Area Collection, Resolution, Cloud Cover, etc.

- **Complex System Constraints**
  - Power, Data Storage, Pointing, Agility, Camera, etc.
Hot topics in Collection Planning

Constellations
Automation
Access to planning process
Capability analysis
Tipping & cueing
The Collection Planning Model
General imaging constraints

What type of picture can you take?
What are you pointing at?
Do you have a good angle?
When do you need the picture?
How much can you see through the lens?
How is the lighting? Is there glare?
Are there other bright objects?
Do you have enough memory / disk space?
Is your battery charged enough?
Can you send your picture?
Do you have WiFi / cell coverage?
Is it ok to take pictures here?
How long until I can take another picture?
…..
High Fidelity Models and Constraints for Collection Planning

- Imaging Model  (imaging modes and targeting ... Agile/Pushbroom/Beam/Frame)
- Maneuver Model  (spacecraft/sensor attitude before and after imaging events)
- Target Access Constraints  (GSD, azimuth, incidence, sun angle, etc.)
- Area Constraints  (South Atlantic Anomaly, Sensor Keep-out Zones, etc.)
- Data Storage  (linear/circular buffer or file-based)
- Contact Scheduling  (ground station locations, antenna agility)
- Bright Object Constraints  (sensor pointing to sun, moon, earth, sun glint)
- Power  (battery charging and depletion, and/or duty cycle limits)
- Weather  (GRIB1/2 forecast)
- System Timing Rules  (mission specific spacecraft timing constraints)
Imaging Types

Fully Agile  Beam  Pushbroom  Frame
Frame Cameras

- Similar to the imager on any digital camera
  - Point and shoot
  - Easy to integrate
  - Small form factor
  - Small field of view

- Take an image, move, take another image
- Can capture “video” by taking a series of images of a single location
- Common for small satellites – Skybox

Planning Challenges
- Agile Satellites – Large field of regard, small field of view
  - Prioritizing/optimizing, settle time, time between images
- Small Satellites – Power planning
- Large Areas – Minimize overlap and eliminate gaps
**Pushbroom**

- **Scans as the satellite moves**
  - Collects along track
  - Some can maneuver cross track between scans
  - Long strips = Good for large areas

- **Planning challenges**
  - Optimize off nadir angle
  - Avoid/minimize slivers for non sun synchronous
  - Lots of data = Recorder/downlink management, power

- **Examples**
  - RapidEye, Landsat
  - Planet Labs satellites are a hybrid
Many non-steerable beams on a non-agile satellite
- Common for SAR (Synthetic Aperture Radar)
  - Not all SAR are beam selection, there are targeted SAR
- Similar to pushbroom = collects as the satellite moves
- Finite scene increments
- Different beams have different capabilities
- Beams look left or right, not straight down

- No weather constraints
- No lighting constraints
- Power intensive
  - Active sensors
  - Not common/possible in small sats
SAR (Synthetic Aperture Radar)

- Planning Challenges
  - Beam selection
  - Scene increments
  - Large, strategic left/right look maneuvers (simple)
  - Only conflicts are cross track conflicts (simple)
  - Coherent stack for change detection

- Examples
  - Radarsat 2, COSMO–SkyMed, TerraSAR X
Most sophisticated sensors/systems
  ◦ Any direction
  ◦ Any duration
  ◦ Sweep forward or reverse
  ◦ Stereo
  ◦ Frequently have multiple imaging modes, line rates, and other mode settings
  ◦ Offset footprints between different imaging modes

Planning Challenges
  ◦ Flexibility to do large area collections – lots of options
  ◦ Large solution space
  ◦ Requires sophisticated planning algorithms
Constellations

- Multiple satellites (2 to 100+)
  - Homogeneous or heterogeneous
  - Constellation of constellations
- Orbits
  - Orbits designed to maximize coverage OR revisit time
  - Sun synchronous is popular
    - Consistent lighting conditions for imaging

Planning Challenges
- Coordinating planning across multiple satellites/operators
- Varying capabilities across constellation
- Planning system performance
Collection Geometry

- Collection angles (elevation & azimuth)
- Sun angles (elevation & azimuth)
Collection Geometry

- Stereo (asymmetry/convergence/bisector)
Power Modeling

- Power generation
  - Account for changing attitude of spacecraft and solar arrays

- Power draw
  - Background power
  - Communication
  - Imaging

- Planning challenges
  - Attitude during imaging can reduce power generation
  - A lot of imaging means a lot of power usage
  - Limits ability to image when spacecraft is in the dark
Service Requests & Area Constraints

- Blackout Periods for satellites or ground antennas
  - Ground antenna maintenance
  - Satellite maneuvers

- Planning Challenges
  - Contact scheduling must avoid antenna blackouts
  - Planning window generation must avoid satellite blackouts

- Restricted areas on the ground and in space
  - Inclusive and exclusive zones
  - South Atlantic Anomaly
Weather Management

Cloud Cover Forecast
- Most recent forecast for an area and time
- Global or Regional Files in GRIB1 or GRIB2 format
- From MDA Federal, AFWA, NOAA or other provider
- Percentage of cloud cover calculated for each area on each satellite pass
- 2D or 3D map visualization

Planning Challenges
- Can filter or score opportunities for imaging based on predicted percent cloud cover
- Shape of clouds doesn’t match shapes of image requests
- Forecasts / clouds constantly changing
- No impact for SAR
Avoid pointing camera or star trackers at bright objects like the sun, moon, or earth
- Single or multiple star trackers

Planning Challenges
- Configurability based on system constraints
  - Allowable angles
  - Number of star trackers (all/none) that can be pointed at bright objects
- Affects maneuver path
- Affects what images collected at what time
  - Might be able to take picture later, even in same pass
Files/bits stored for each image
- Sensor specific data record rate based on area / size, band, resolution, and other factors
- Record rate should also account for compression
- Standard workflow = record, playback, unprotect, delete

Planning Challenges
- Limited resource!
- Configurable downlink and deletion options
- Score, priority, FIFO, priority preemptive
Contact Scheduling

- Communication contacts required for uplink of tasking and downlink of image data
  - Ground station parameters include location, elevation, and obscuration masks
  - Satellite parameters include antenna agility, antenna field of regard, and ephemeris

Planning Challenges

- More contacts = more responsive (uplink & downlink)
- More contact time = more images
- More resources (satellites & ground stations) = need to deconflict contact schedules
System Timing Rules

- Miscellaneous timing constraints
  - Minimum time between images (regardless of slew)
  - How soon after umbra can you start imaging
  - Duty cycle on imagers
  - Min/Max strip length
  - Minimum time between contacts
  - Minimum contact time
  - Pre/post contact no imaging time
  - Recorder buffers
Review of Constraints

- Imaging
- Satellite Agility
- Recorder Management
- Contacts
- Bright Objects
- Power
- Service Requests
- Restricted Areas
- Weather
- System Timing Rules