Satellite Fleet Operations Using a Global Ground Station Network

Naomi Kurahara
Infostellar

Japanese university satellites

Image via University Space Engineering Consortium, http://unisec.jp/wp/wp-content/uploads/2016/06/UNISEC_Satellites_160120_JP_s.jpg

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Next steps for the small satellite community

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Satellite bus technology has progressed, technology demonstrations have been completed.

What do we do next?
How do we get a research budget?
How can we create sustainable space applications?

Most of the next satellite mission require satellite constellations.
How do we operate 10s/100s of satellites?

Contents

Satellite Fleet Operations Using a Global Ground Station Network

What is effective constellation operation?

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First, what is the purpose of satellite operation in general?

- Execute a mission (one time or periodic, manual or automatic)
- Conduct satellite maintenance
    - Maintain each component

As a constellation...

- Mission execution is carried out by multiple satellites.
- Satellite maintenance (housekeeping operations) should be carried out automatically. Human operators monitoring hundreds of satellites is inefficient.

Key concepts of satellite operation

- Satellite mode (Pre-defined)
- **Procedure (Pre-defined)**
- Operation phase (Pre-defined)
  - Initial operation phase
  - Nominal operation phase
  - EOL phase
  - Emergency
- Planning

Satellite mode

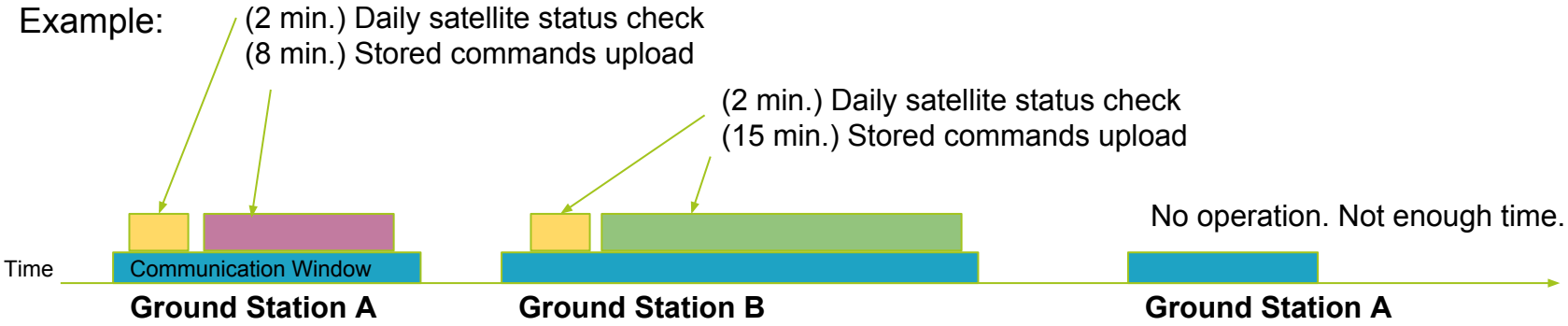
- A satellite mode defines a configuration of satellite
  - Eg. Mission execution mode, maneuver mode, battery recovery mode, etc.
- For each mode, followings are fixed
  - On/Off status of every components
  - Mode of each component turned on
  - Power consumption

Procedure

- A series of commands and telemetry to be checked in order to execute an operation
- Optionally includes sub-procedures
  - Depth determined by satellite operator

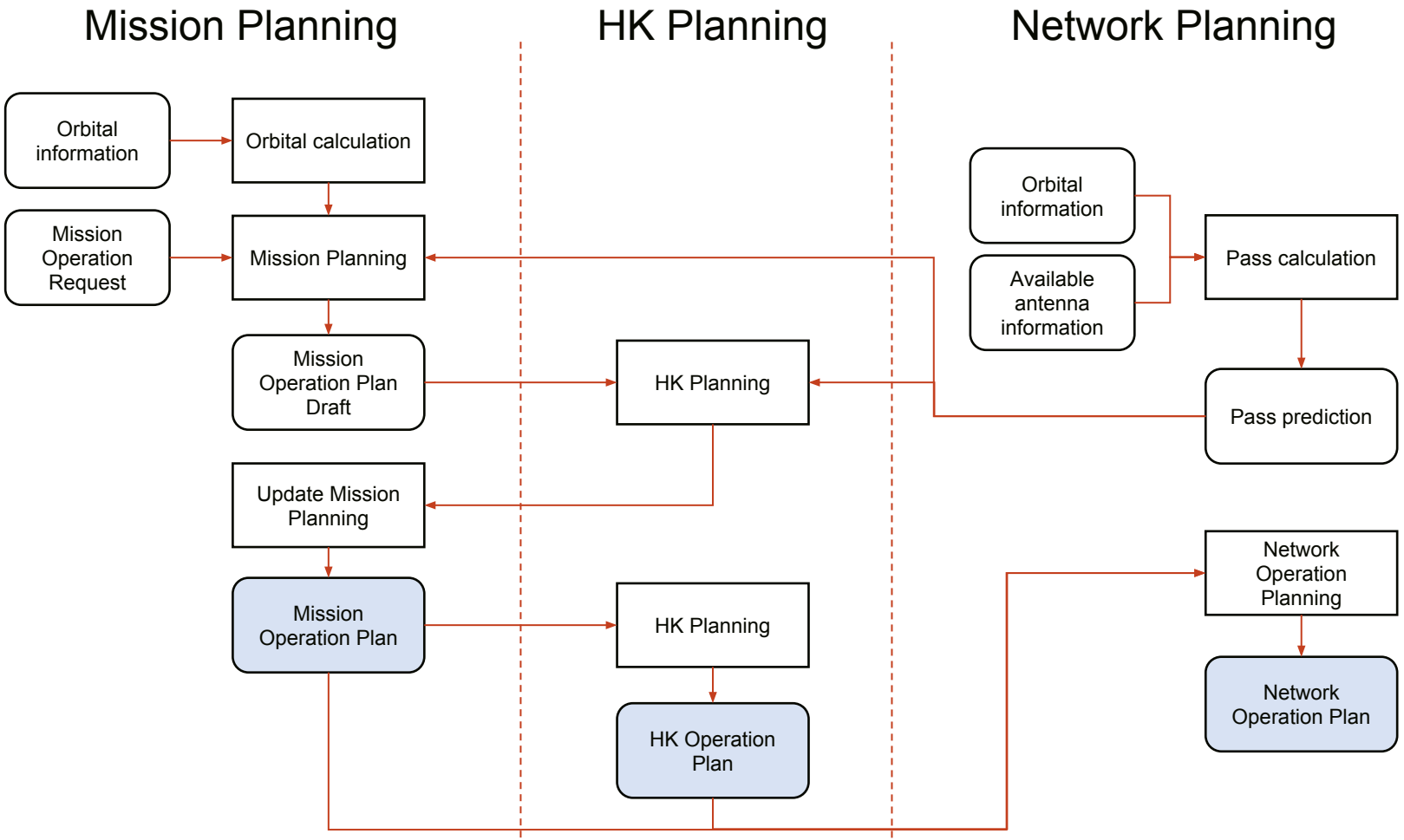
Procedure-oriented planning

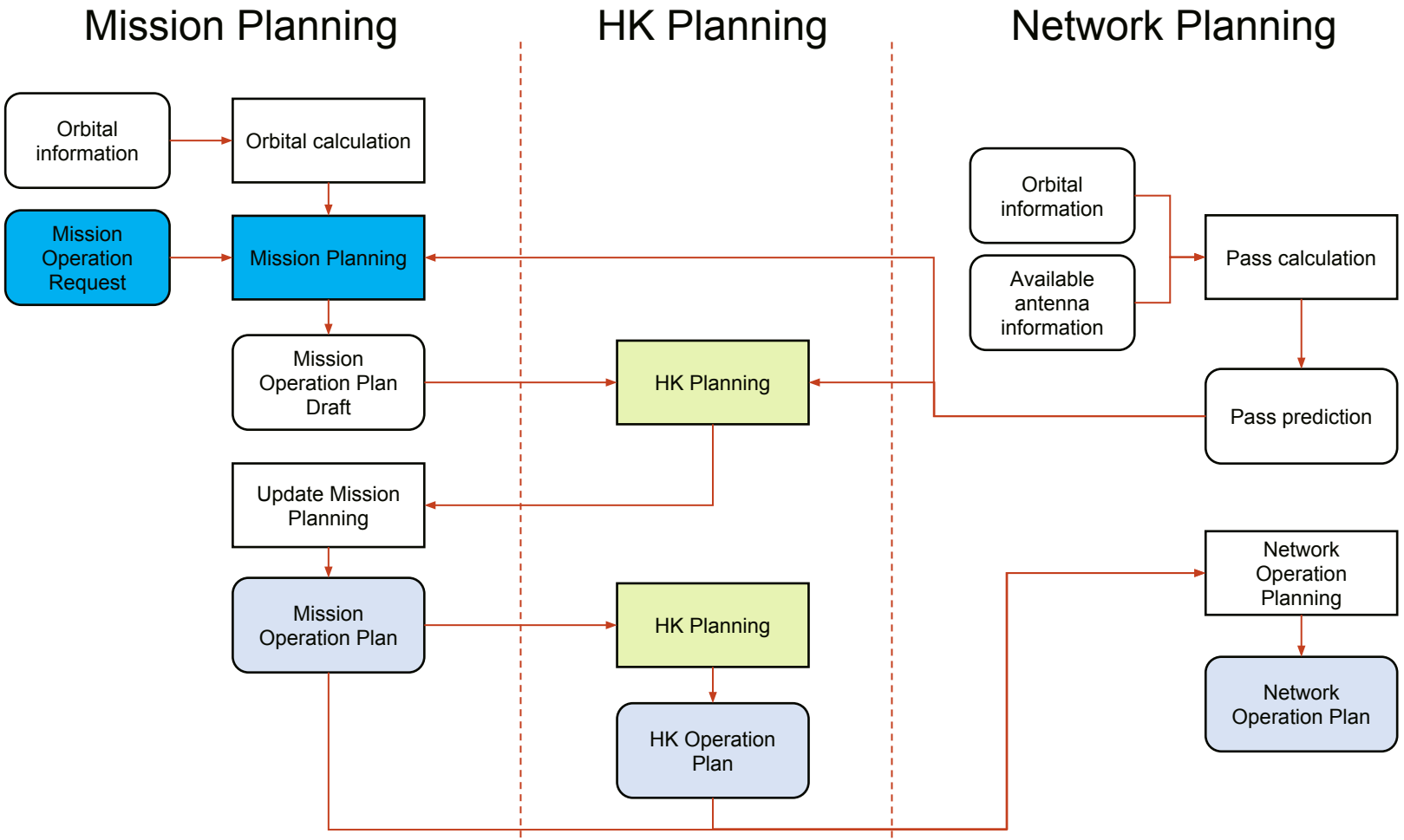
- A process for building a satellite operation plan
  - What do you want the satellite to do and when?
  - Which procedures are used?
    - Satellite mode change required?
    - Which components are controlled?
  - How much time does it take?



Planning Process (1/2)

- 3 types of planning
  - Mission execution planning
    - For mission execution
  - Housekeeping operation planning
    - For satellite maintenance
  - Network operation planning (Antenna allocation)
    - Based on available antennas


Mission Planning
HK Planning
Network Planning
Orbital information
Orbital calculation
Mission Operation Request
Mission Planning
Mission Operation Plan Draft
HK Planning
Update Mission Planning
Mission Operation Plan
HK Planning
HK Operation Plan
Orbital information
Available antenna information
Pass calculation
Pass prediction
Network Operation Planning
Network Operation Plan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Pass calculation
Pass prediction
Network Operation Planning
Network Operation Plan

Problems

1. **How to define mission operation requirements → How to plan mission operation**
2. **How to automate, i.e Autonomous HK operation**
3. The number of available antennas creates a bottleneck in satellite operation planning

Questions

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- What is the constellation’s mission?
- What kind of mission instruments are on board?
  - How large is one unit of mission data?
- Is there a specific mission target area or user?
- How much mission data can the satellite hold at maximum?
- What is the communication data speed?
  - Mission data downlink
  - HK uplink
  - HK downlink
- How long does the satellite transmitter run?
  - Nominal case
  - Maximum case
- What does the operator need to do for housekeeping operation?
- What does the operator need to do for mission operation?

Problems

1. How to define mission operation requirements → How to plan mission operation
2. How to automate, i.e Autonomous HK operation
3. **The number of available antennas creates a bottleneck in satellite operation planning**

Ground System Design

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- How much data needs to be downlinked to the ground?
  - Amount of mission data
  - Amount of housekeeping data

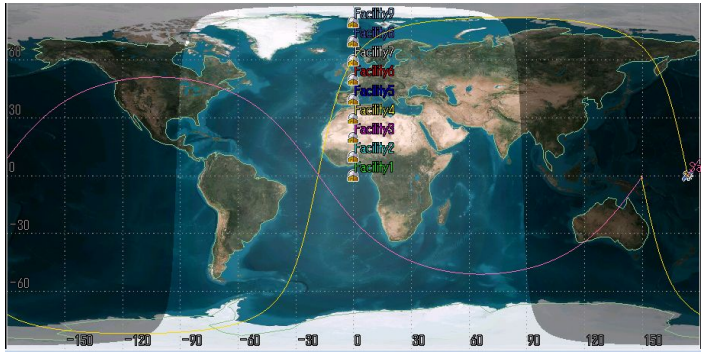
- How long does a satellite communicate with a single ground station?

Analysis of Pass Duration (1/2)

- Simplified analysis for Polar Earth Orbit and ISS orbit
- Orbit and ground station parameters:

Orbit Parameter	Value	
Apogee Altitude	600 km	400 km
Perigee Altitude	600 km	400 km
Inclination	98 deg	51 deg
Argument of Perigee	0 deg	0 deg
RAAN	0 deg	0 deg

	Ground Station Location
Ground Station A – I	Latitude: 0, 10, 20, 30, 40, 50, 60, 70, 80deg Longitude: 0 deg Altitude Reference: WGS84



Analysis of Pass Duration (2/2)

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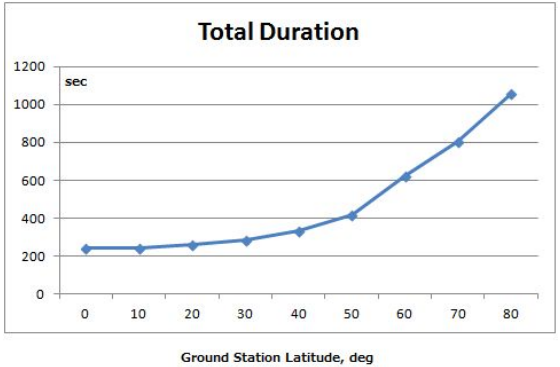
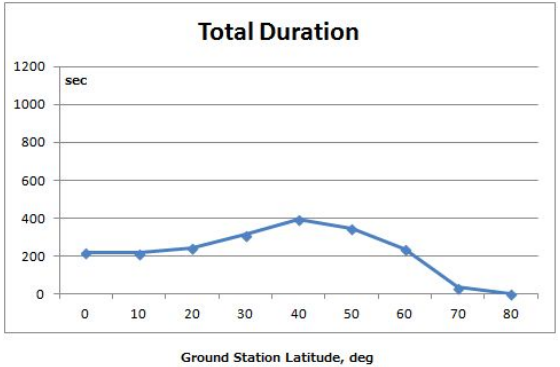
600km, 98 deg Inclination

Latitude (deg)	Number of Pass, Week/day(ave.)	Total Pass Duration/Week (min)	Average Pass Duration/Day (min)
80	90/13	1056	150
70	74/11	807	115
60	64/9	625	89
50	42/6	417	59
40	33/5	331	47
30	29/4	286	40
20	26/4	262	37
10	24/3	245	35
0	24/3	240	34



400km, 51 deg Inclination

Latitude (deg)	Number of Pass, Week/day(ave.)	Total Pass Duration/Week (min)	Average Pass Duration/Day (min)
80	0/0	0	0
70	12/2	34	4
60	30/4	234	33
50	36/5	344	49
40	42/6	391	55
30	39/6	312	44
20	29/4	242	34
10	25/4	215	30
0	27/4	216	30



Questions

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- How many HK operations actually happen per day?
  - What is the minimum length of time for HK operations?

- How many mission data downlink operations actually happen per day?
  - What is the minimum length of time for mission data downlink operations?

Ground System Cost (CAPEX/OPEX)

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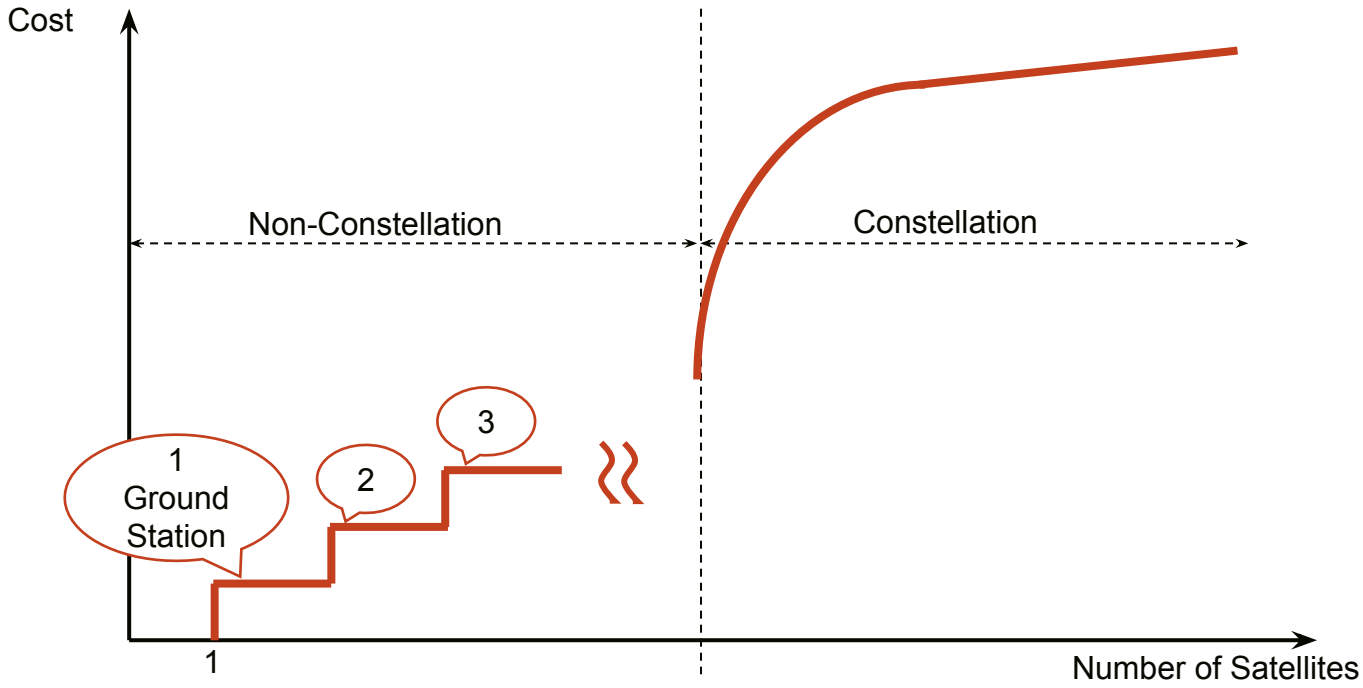
Ground system cost doesn't increase linearly.



Summary

- More research is required to discuss effective mission planning for constellations.
- Significant potential in networking in order to connect and use discarded passes.
- More research required to determine how many passes can realistically be used.

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Thank You

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