Micro-Satellite Project Mission and Cost Model

- *Guidance Book* -

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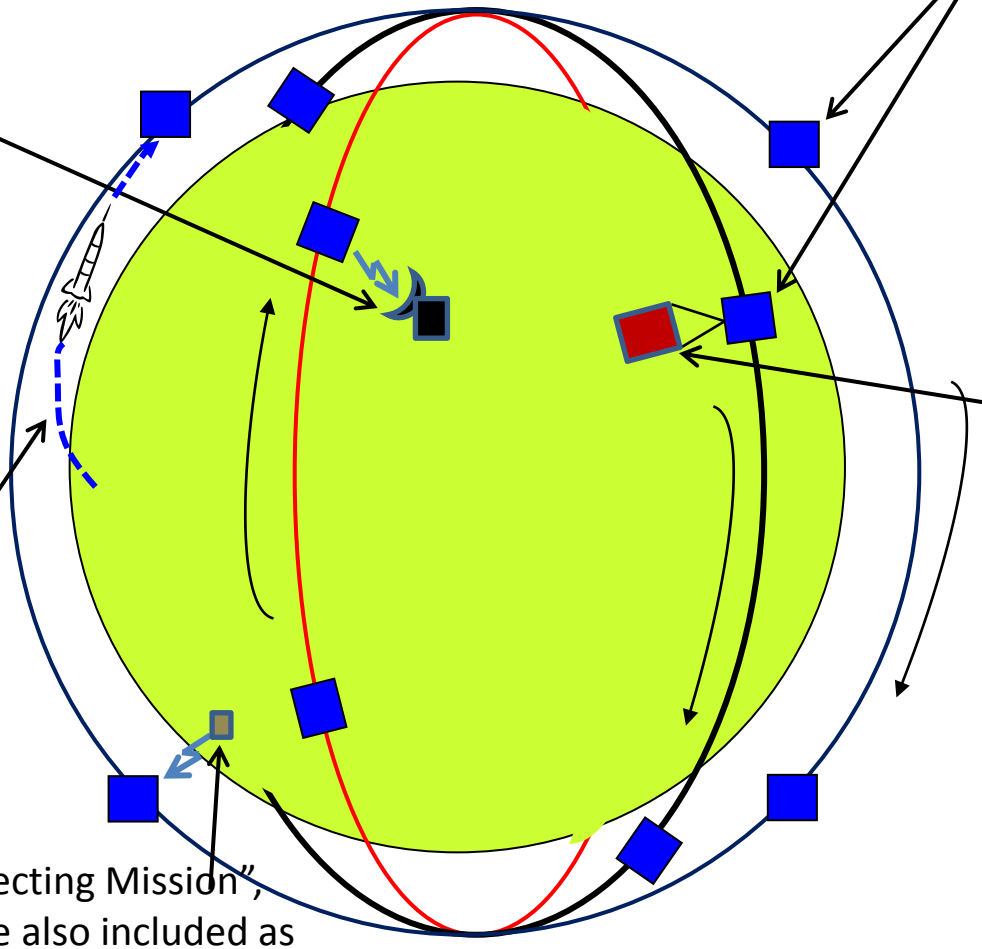
Nomenclatures

Term	Description
bus	Key components that most satellites are equipped with such as computer, control system, battery, solar panel, communication system, and frame structure of the satellite.
payload	Components of satellite which serve the mission function such as a camera system for remote sensing, a rental space/camera for rental space and an antenna/receiver for information collection.
remote sensing	A type of satellite mission to obtain information such as images of the ground surface and temperature distributions.
GSD (Ground Sample Distance)	Resolution on the Earth surface. GSD 5m means the satellite camera can recognize almost 5-m size object on the Earth surface.
Kelvin	Unit of temperature. 0 degree Celsius equal to 273 Kelvin.
uplink	Sending data signals from a ground sensor to satellite(s)
downlink	Sending data signals from a satellite to ground station(s)
piggyback launch	A launch style where small satellites ride on a rocket to carry a main medium to large size satellite.
downlink period	Total time to send signals from the satellite to ground stations per day.
downlink latency	The time it takes from satellite emergent data collection to downlink.

Contents

Key System Elements for Satellite Mission

(1)(2)(3) are the system elements and constitute the total cost.



(1) Satellites
In this figure, a total 12 satellites are placed in 3 orbital planes (4 satellites per plane).

(2) Ground Stations
Receive data such as images or sensor data from satellites.
(The data transmission from satellite to ground is called "downlink")

(3) Launch Rocket
Launch satellite to the Earth orbit

Satellite Mission:
This figure shows remote sensing mission to capture Earth images using visible or infra-red sensor.
Other missions include;
-Rental space
-Information collecting

In the "Information Collecting Mission", small ground sensors are also included as system elements which send data to the satellite (sending data to satellite is called "uplink")

Effects of Increased Number of Satellites and Ground Stations

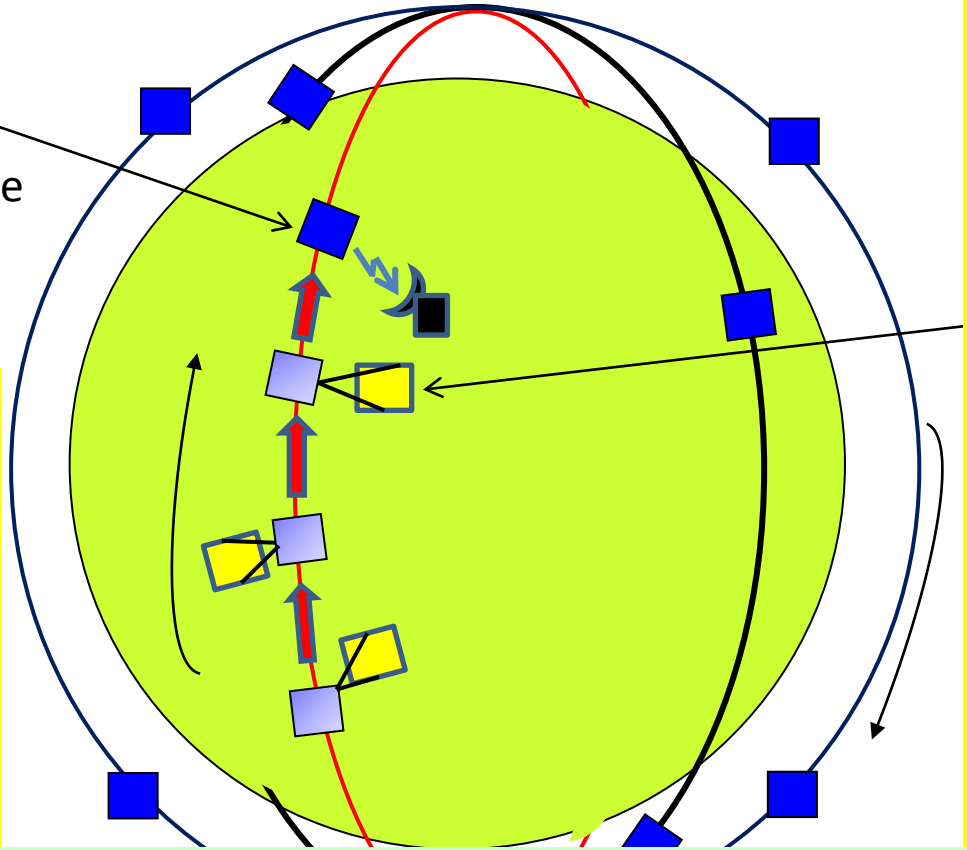
The number of satellites and ground stations are important design criteria. The merits of more satellites against the increased costs are trade-off.

- With more satellites, you can obtain
  - More coverage of the Earth per day for remote sensing mission.
  - More frequent observation of the same area for remote sensing mission.
  - More data can be received from ground sensors for information collecting mission.
  - More space available for rental space mission.

- With more ground stations, you can obtain
  - More time to receive satellite data, resulting in, for example, more image data can be downlinked per day
  - Less latency to downlink urgent data

Remote Sensing Mission

Only when satellite flies over a ground station, image data are downlinked to the ground with certain downlink speed.



Satellite takes images of the area below it flies using optical or infra-red camera and store them in the memory.
The mission specs include;

1) Optical or infra-red camera
2) Ground resolution (GSD)
3) Size of the image areas (such as 200km x 200km)
4) Temperature resolution level for infra-red sensor

A satellite waits to downlink image data until it flies over the ground station. This "latency" can be calculated as;

6 hours/G

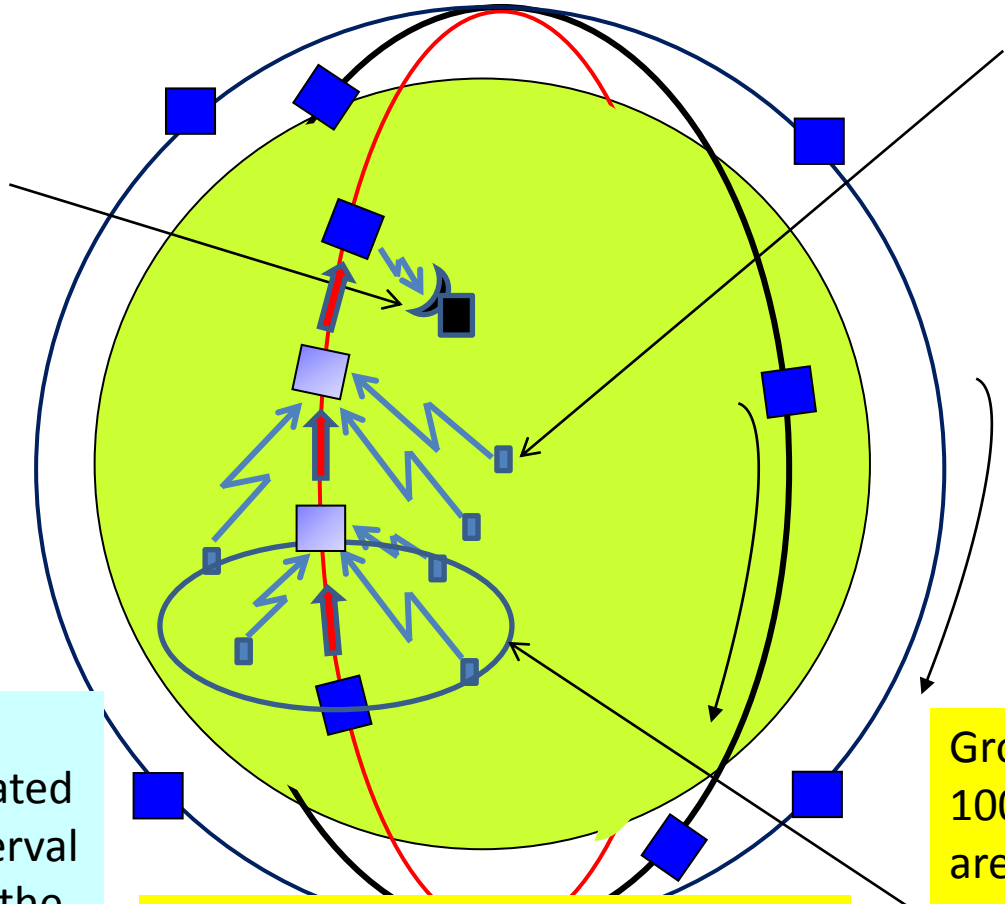
where G is the number of ground stations.

A satellite can communicate with one ground station for 40 minutes (2400 sec) per day. With G ground stations, the satellite can downlink for 2400 x G sec per day. The number of images sent per day can be calculated as;

2400 x G x downlink speed /data size of one image

Information Collecting Mission

Satellite downlinks the stored data to the ground station when it flies over.



Many ground sensors on the Earth transmit data continually. The satellite can receives data signals when it flies over them (called "uplink"). The amount of data from each sensor, the number of sensors, and data transmission speed need to be specified.

When there are N satellites in coordinated orbit, the revisit interval of the satellite over the ground sensors is calculated as 0.5/N day (for non-coordinated orbit, 1/N day)

Then the time allotted to one ground sensor for transmitting data to the satellite per satellite visit is calculated as 600sec/M.

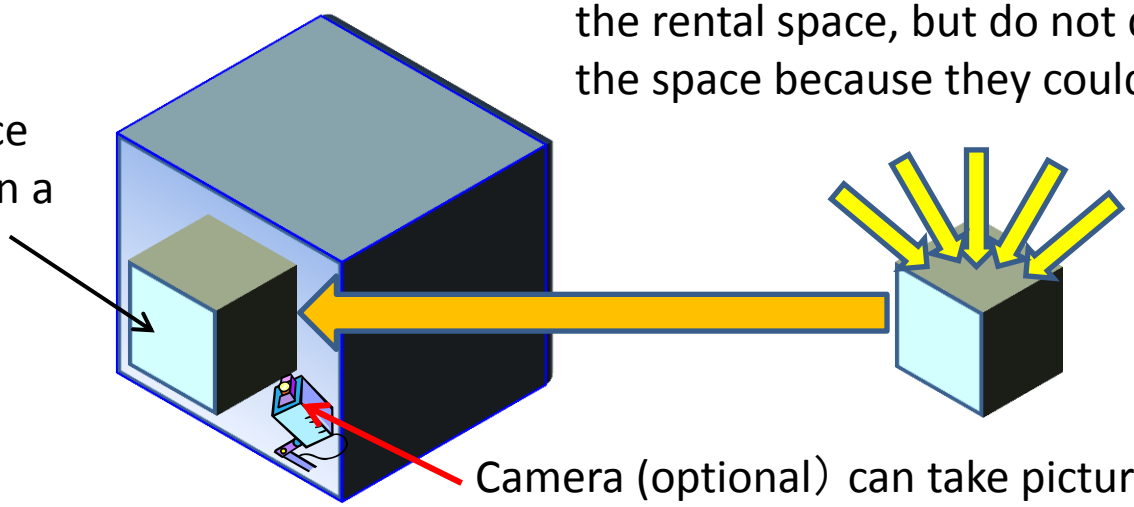
Ground sensors within 1000 km radius circular area can communicate with the satellite. First calculate the averaged number "M" of ground sensors within one circle.

Rental Space Mission

- Items of customers can be launched into space with “onboard fee” in “rental space” of the satellite.
- The items stored in the rental space can be photographed in space (with the Earth as background, for example) if an optional camera is also mounted . Images of the items can be downlinked to ground so that customers can purchase.

You can store as many items as you want in the rental space, but do not deploy them into the space because they could be debris.

A rental space
10 to 40 cm^3 space can be provided in a satellite where customers’ items can be stored.

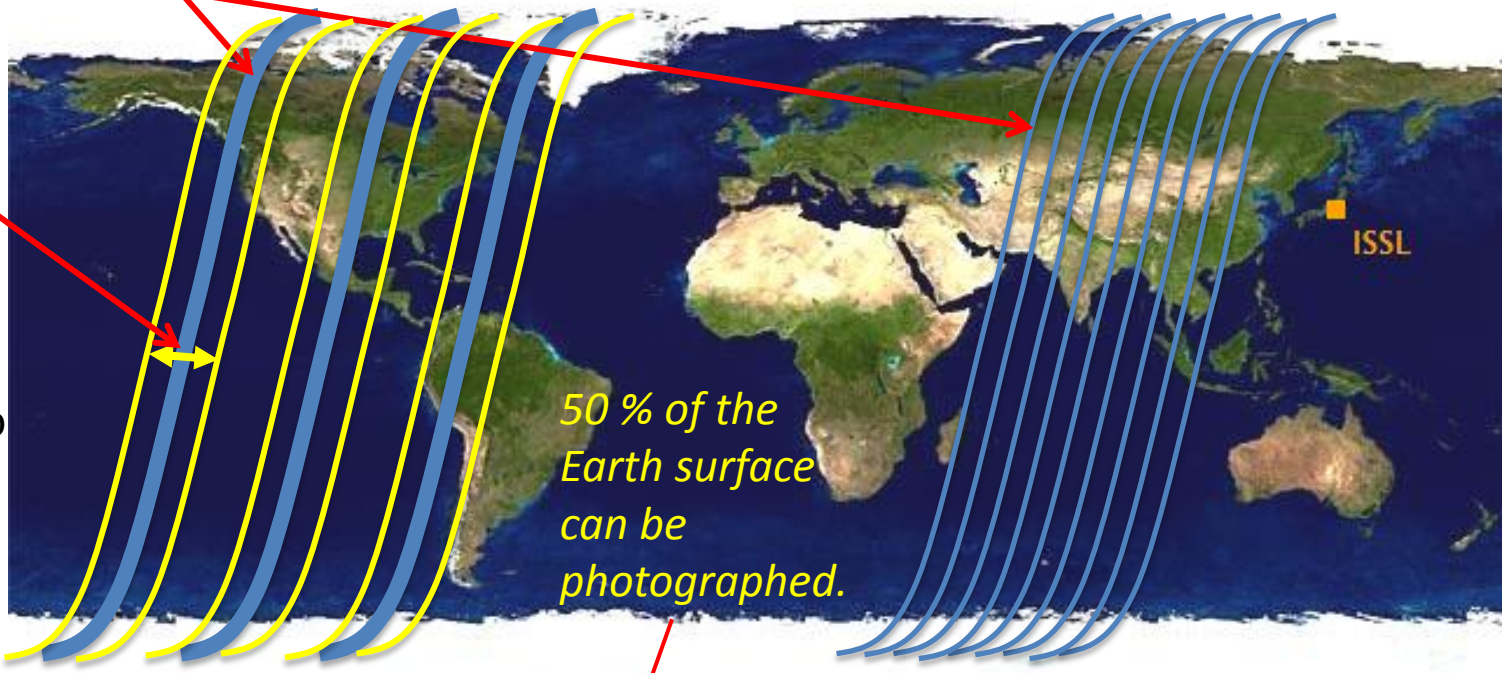


Camera (optional) can take pictures of the items and send them to the ground.

Coverage Area and Revisit Interval

Trajectory of satellite over the Earth

You can take photos within these two lines



Day 1 2 3 ------
11 12 13 ------
Revisit interval: 10 days
Coverage area: 50 %

Day 1 2 3 4 5 6 7 8 9 ----------
41 42 43 44 45 46 47 48 49 ------
Revisit interval: 40 days
Coverage area: 100 %

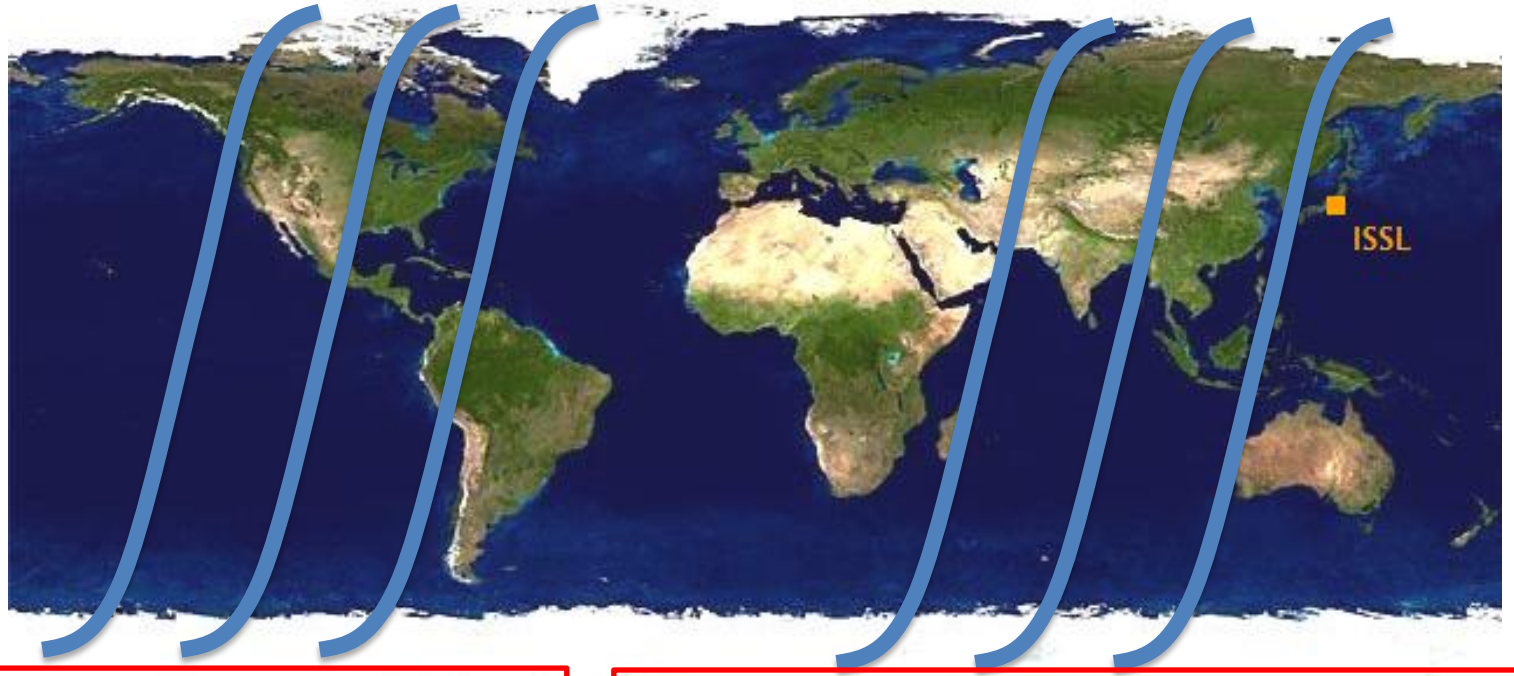
The satellite comes back to the same place after 40 days.

One satellite case: You can choose the revisit interval (L days) to estimate the percentage of the Earth coverage, which can be roughly calculated as 5 x L (%). (If this value exceeds 100 %, then it is recognized as 100% which means the satellite can take photos of the entire Earth surface.)

Multi-Satellites Orbit Designs (Coordinated Orbits)

One Satellite Case

2 Satellites Case



Day 1 2 3 ------

11 12 13 ------

Revisit interval: 10 days

Coverage area: 50 %

Sat #1 day 1 2 ---

6 7

Sat #2 day 1 -----

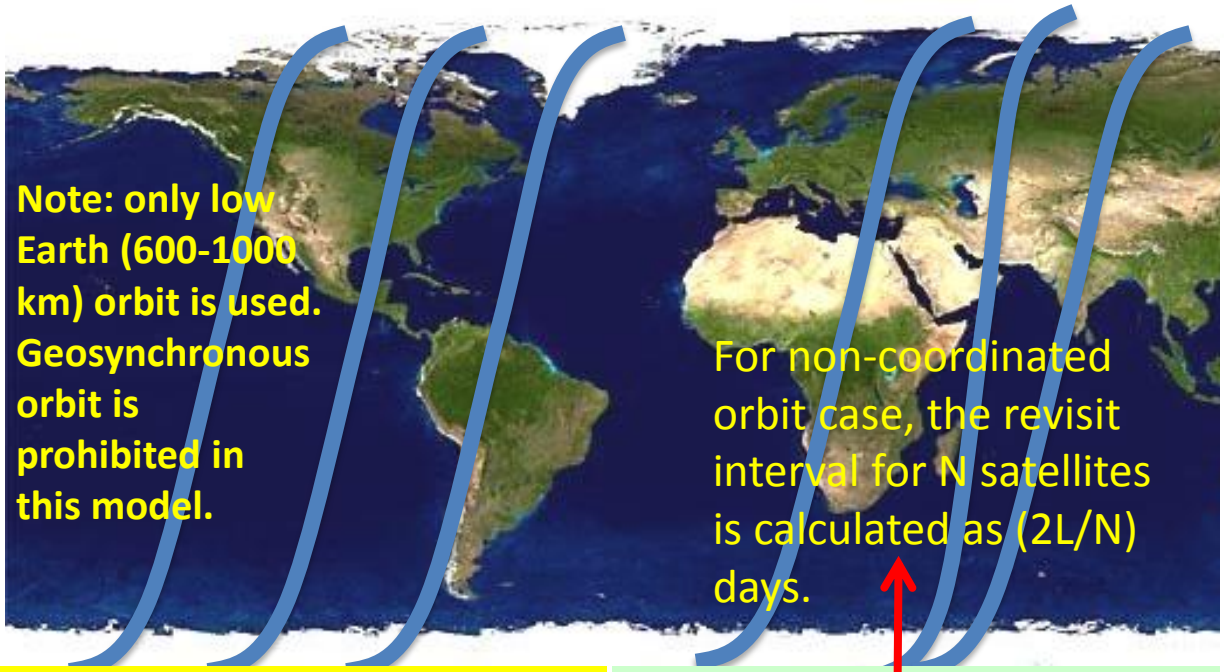
6 -----

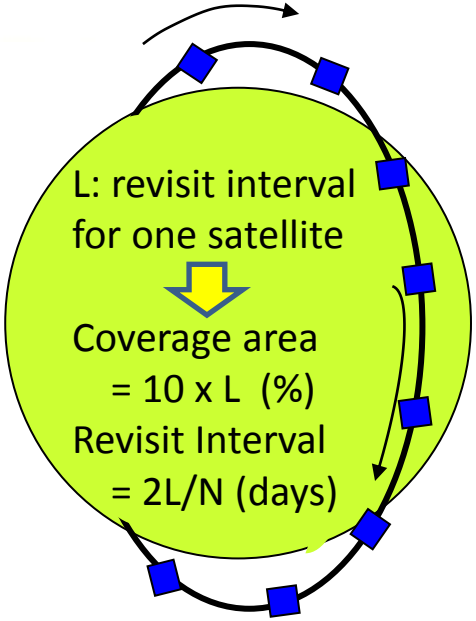
Revisit interval: 5 days

Coverage area: 50 %

N (more than one) satellites can reduce the revisit interval to (L/N) days where L is revisit interval for one satellite. Coverage area will be the same as one satellite case.

Dependency on Launch Configuration





Sat #1 #2 #3

If you choose "coordinated launch", the equally spacing orbits can be achieved with higher costs.

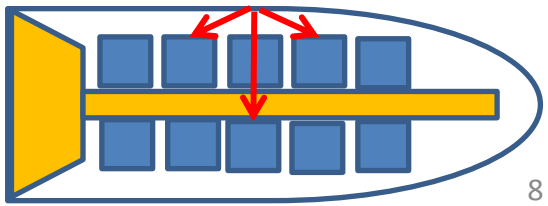
Sat #1 #2 #3

If you choose non-coordinated launch, orbit paths could be poorly configured, but at lower costs.

If you purchase one whole rocket, you can launch maximum of 15 satellites into the same orbital plane as shown above.

This launch is called "piggyback" which means small-satellites get "hitch-a-ride" on a rocket launching a larger main satellite.

Many small satellites are installed in one rocket



Project Cost Breakdown (1)

- Satellite Cost Model (*1.1 and 1.2 are both required*)
  - 1.1 Bus Cost
    - Cost depends on bus performance level (low, medium, high)
  - 2.1 Payload Cost
    - Cost depends on mission category and performance
    - Four categories (*you can select from 2.1.1 – 2.1.4*)
      - 2.1.1 Remote sensing with visible light (R,G,B, near infra red + panchromatic image acquisition. "GSD 5m" means that the sensor can detect 5m object on the Earth ground)
      - 2.1.2 Infra-red sensor to detect temperature of the ground ("temperature resolution X" means the sensor can discriminate X Kelvin temperature difference and ground resolution means GSD)
      - 2.1.3 Communication payload can receives data from many sensors on the ground and sends them back to the ground station. Cost depends on data rate to receive data from ground sensors)
      - 2.1.4 Rental space provides a "space" for bringing some items to space in which you can put anything. An optional camera can capture images of the items with space or the Earth as background. Cost depends on the size of the space and whether the optional camera is installed or not)

Project Cost Breakdown (2)

- Ground Station Cost Model *(3.1-3.3 are all required.)*
  - 3.1 Development cost is required one time when the project starts
  - 3.2 Operation cost is required for personnel to operate the ground station to receive data from satellites (yearly cost)
  - 3.3 Data analysis cost is required to process the date from satellites (system and personnel cost per year)
- Launch Cost Model *(you can select 4.1 or 4.2)*
  - 4.1 One whole rocket can be purchased to launch many (maximum 15) satellites to the same orbital plane.
  - 4.2 Single satellite launch by piggyback style can be possible to launch satellites to "coordinated orbits" (with higher cost) or "non-coordinated orbits" (with lower cost).

- Cost for ground sensors with uplink capability (2.1.4) should be added for information collecting mission