

A study for influence of optical links to existing space communication architecture

Japan Aerospace Exploration Agency

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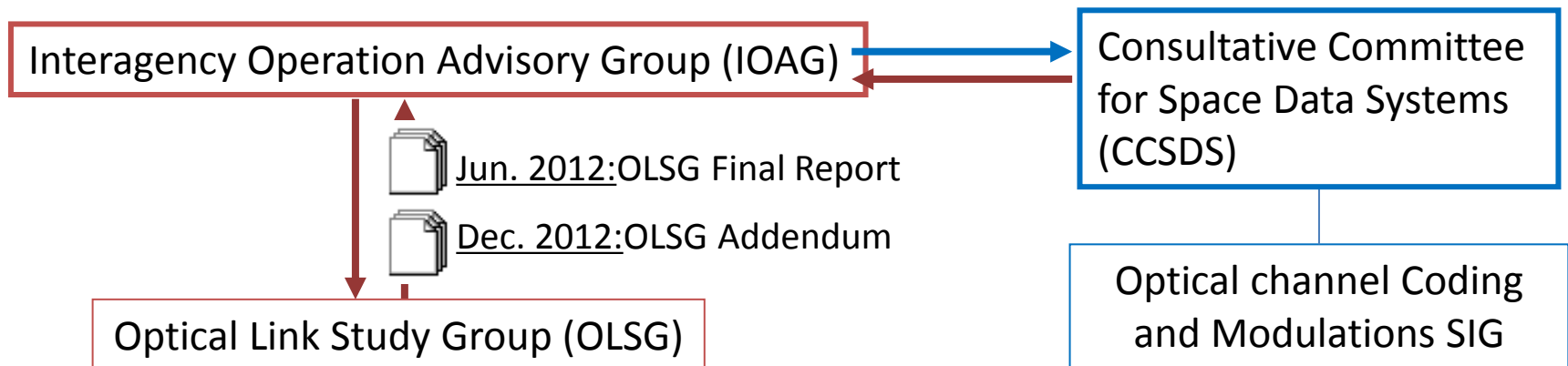
- Introduction of activities on optical link
- Issues for adding Optical stations to the existing ground segment
- Introduction of the existing ground segment
- Study on updating ground segment
- Study on applying new technology to optical link
- Results



- Optical terminal
 - Lightweight component, Power saving, High speed link
 - Distributing satellite resources to mission components
 - Easier to put difficult missions into reality
- Each space agency is planning to construct Optical Link facilities
- But it is difficult for one agency to construct Optical link facility
 - Location of ground segment restricted by meteorological condition
 - Many ground segments required to complement lost data by link disruption (e.g. cloud)



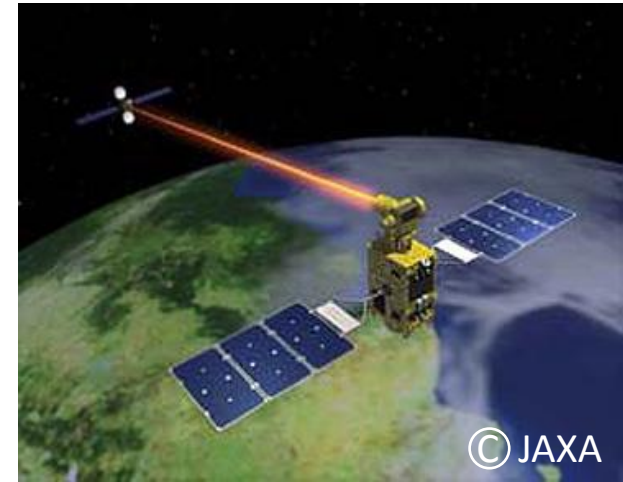
- Difficult issue for one agency can be resolved by interoperability among many agencies
- Started activities to achieve interoperability of optical link
 - 2010 : Optical Link Study Group inaugurated
 - 2012 : Preparation Report
 - Operation scenarios (e.g. LEO, deep space)
 - Standardization guidance recommended (e.g. wavelength, acquisition sequence)



Related organizations



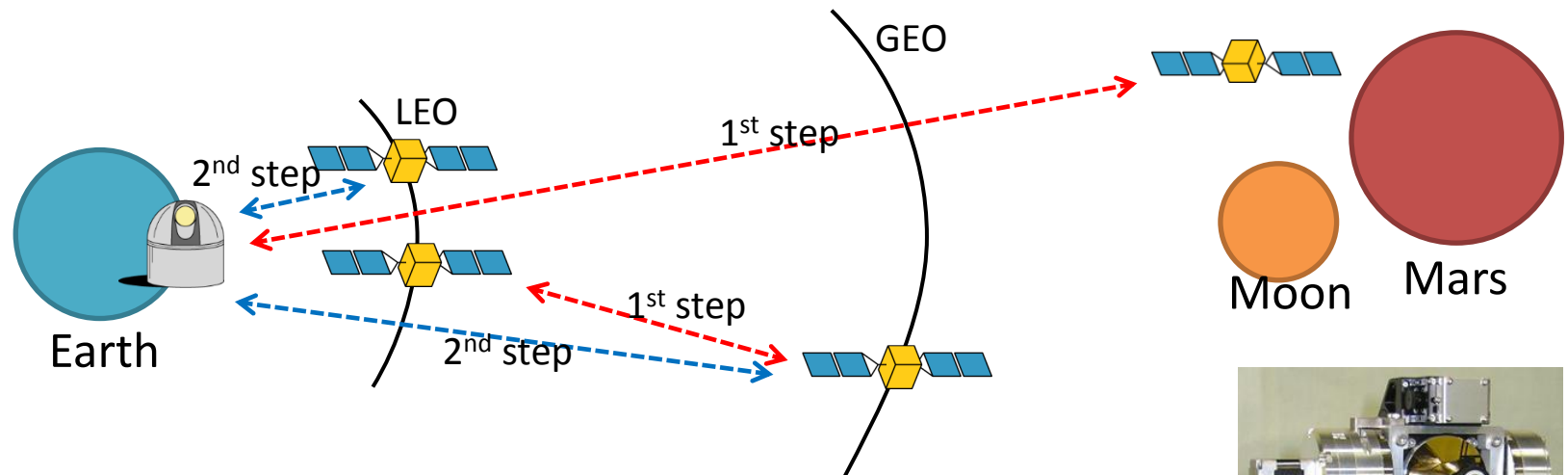
- OICETS
 - Purpose :optical link demonstration
 - Specifications
 - Wight: about 550 kg
 - Size: about 0.78 m X 1.1 m X 1.5 m
 - Design life: 1 year
 - Orbit: circular orbit (Altitude: 500 km)
 - Lunch: 24 August 2005
 - Outcome
 - 9 December 2005: successful Inter-satellite optical link for ARTEMIS (ESA)
 - 31 March 2006: successful optical link between satellite and ground





Japan Aerospace Exploration Agency (JAXA)

- Studying optical link use for Deep space missions and Earth observation missions (inter-satellite link) as a first step



National Institute of Information and Communications Technology (NICT)

- Developing optical terminal for the nano-satellite; SOTA



Reference: Optical Link Study Group Final Report



- As international and domestic trends, how to update the ground segment matters a lot for introducing optical link.
- Introduction of optical link into the exiting ground segment would require consideration to Japanese past course of development in the field
 - We hope to prove that introduction of optical link is not too hard by showing that an agency with much less human resource and budget than NASA/ESA can also achieve it.
 - If it is proved, we consider that agencies and companies which has RF facility will achieve optical link and interoperability progress.



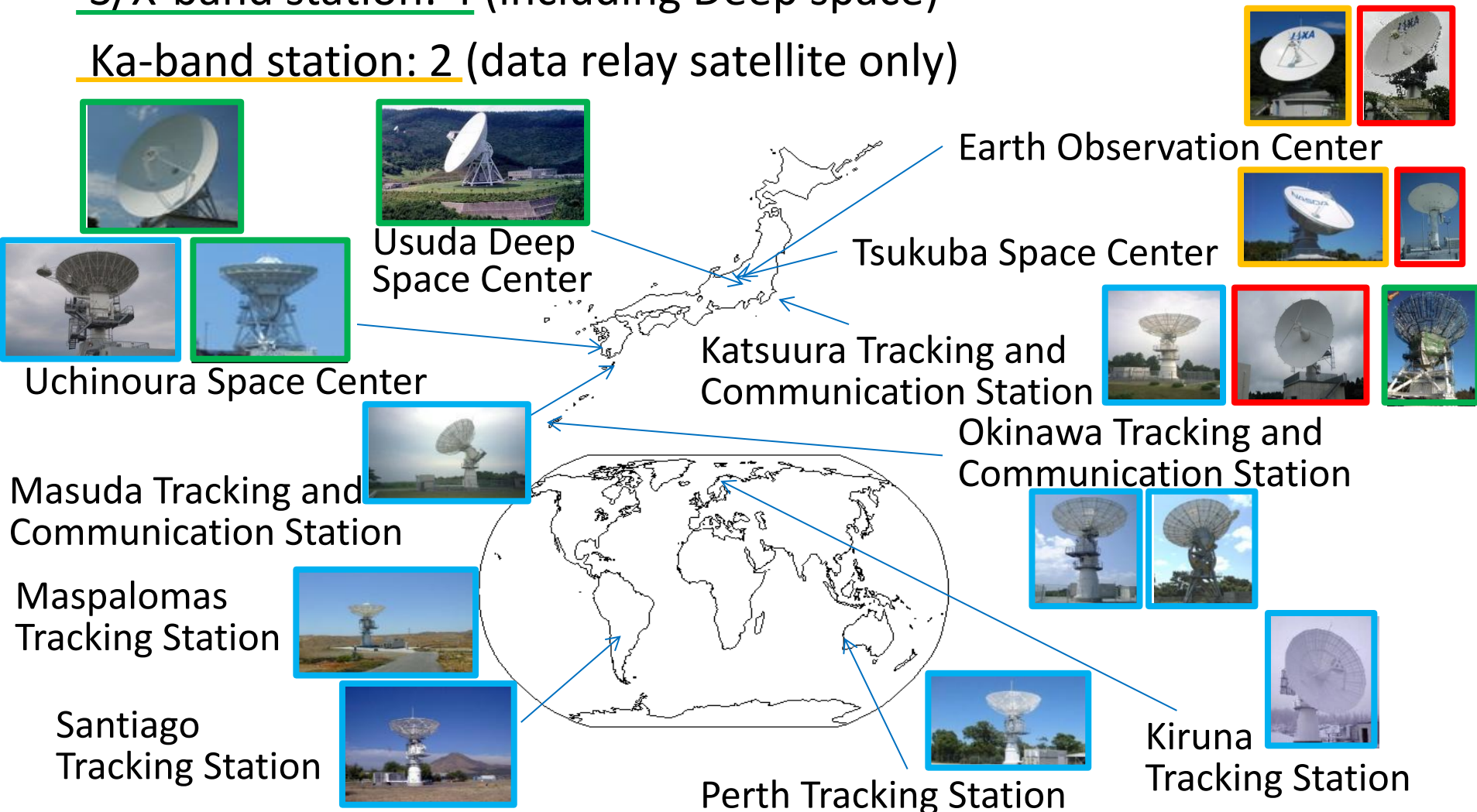
JAXA Ground Segment



S-band TT&C station: 9, X-band mission data receiving station: 3

S/X-band station: 4 (including Deep space)

Ka-band station: 2 (data relay satellite only)

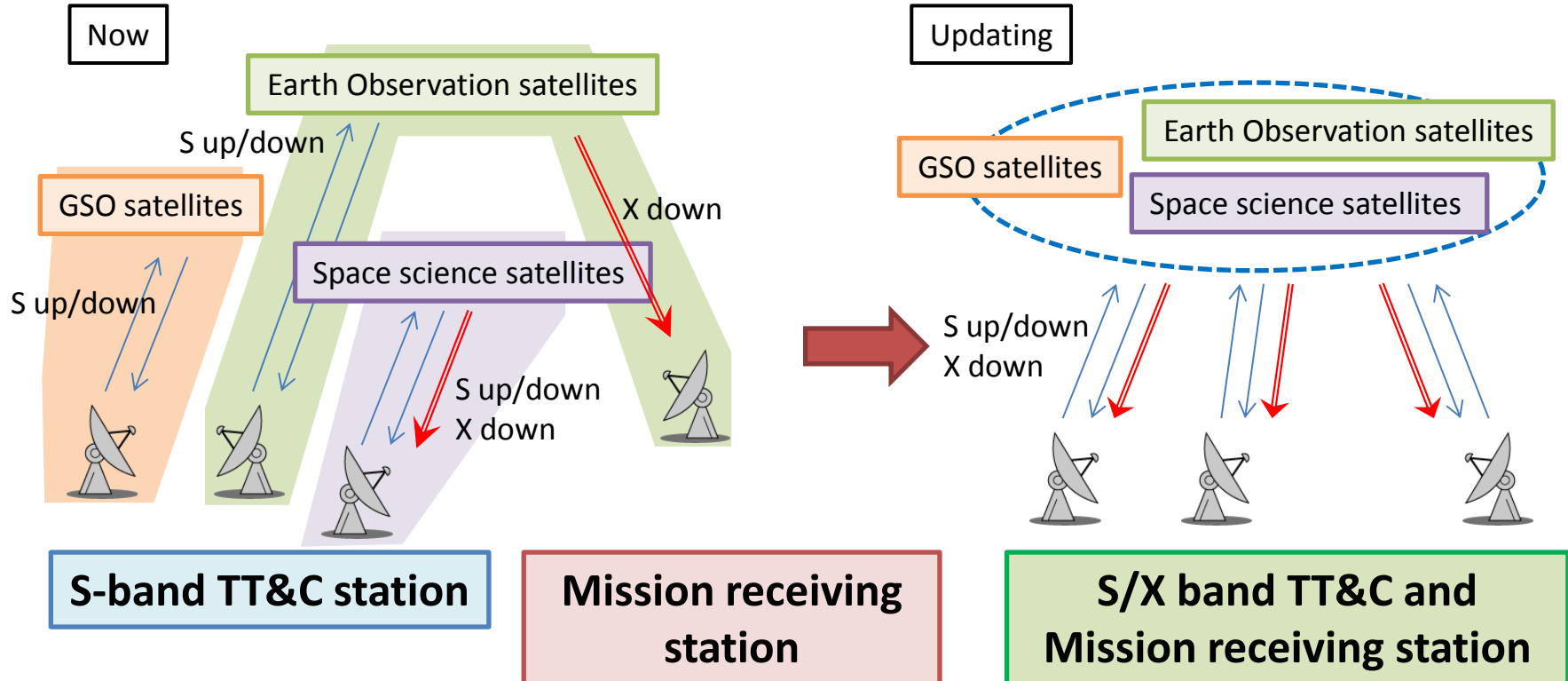




Updating Ground Network



- Restricted ground station for each satellite operation
- ↓
- Selectivity of ground station will be increased
 - Running cost will be increased by reducing ground stations



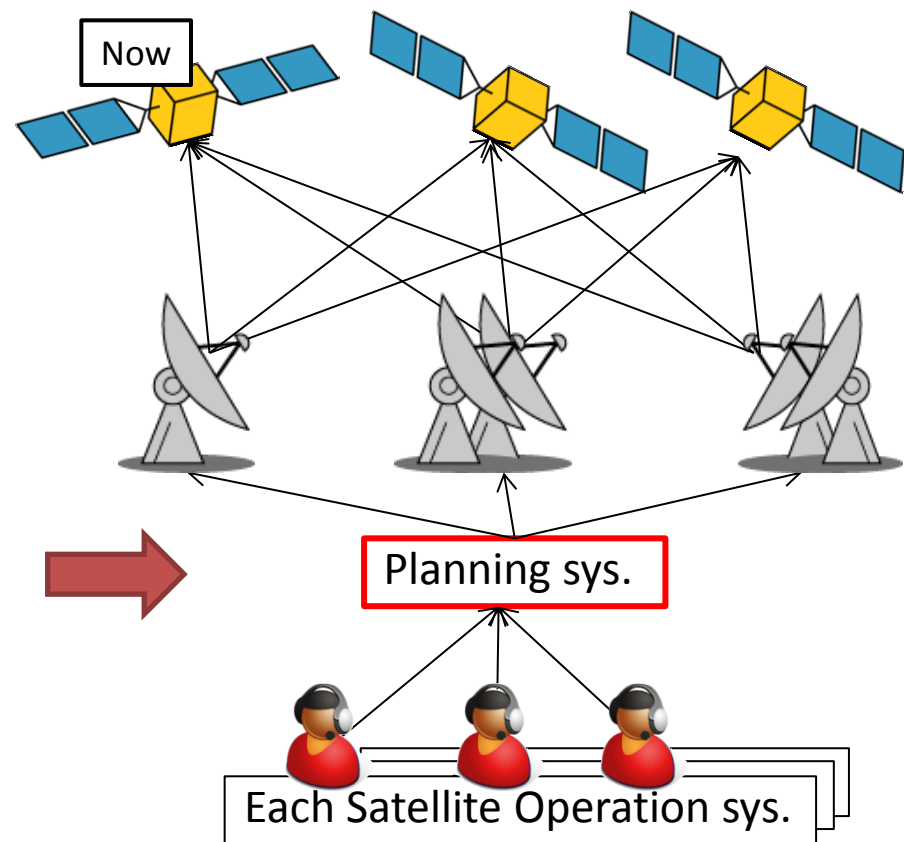
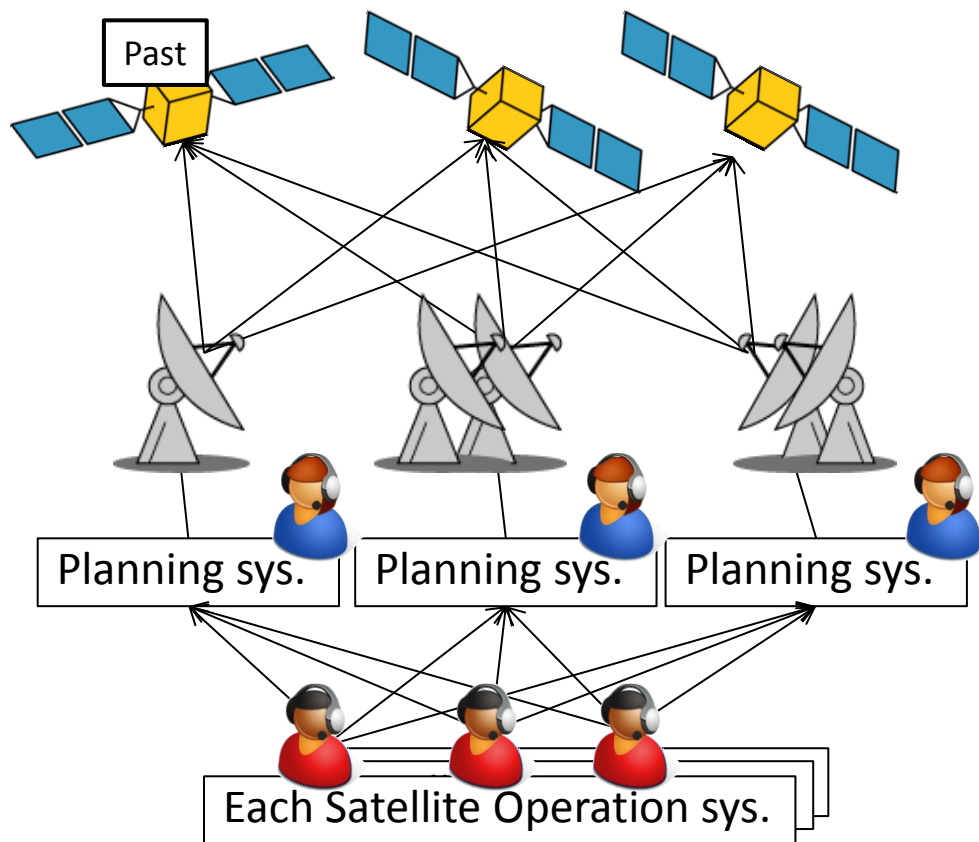
Note: Deep space mission is assigned to a dedicated station



Updates with Planning System



- Each satellite operator used to reserve ground NW planning systems as required
- ↓
- By consolidating the planning systems, each satellite operator can make reserve requests through only one ground NW planning system

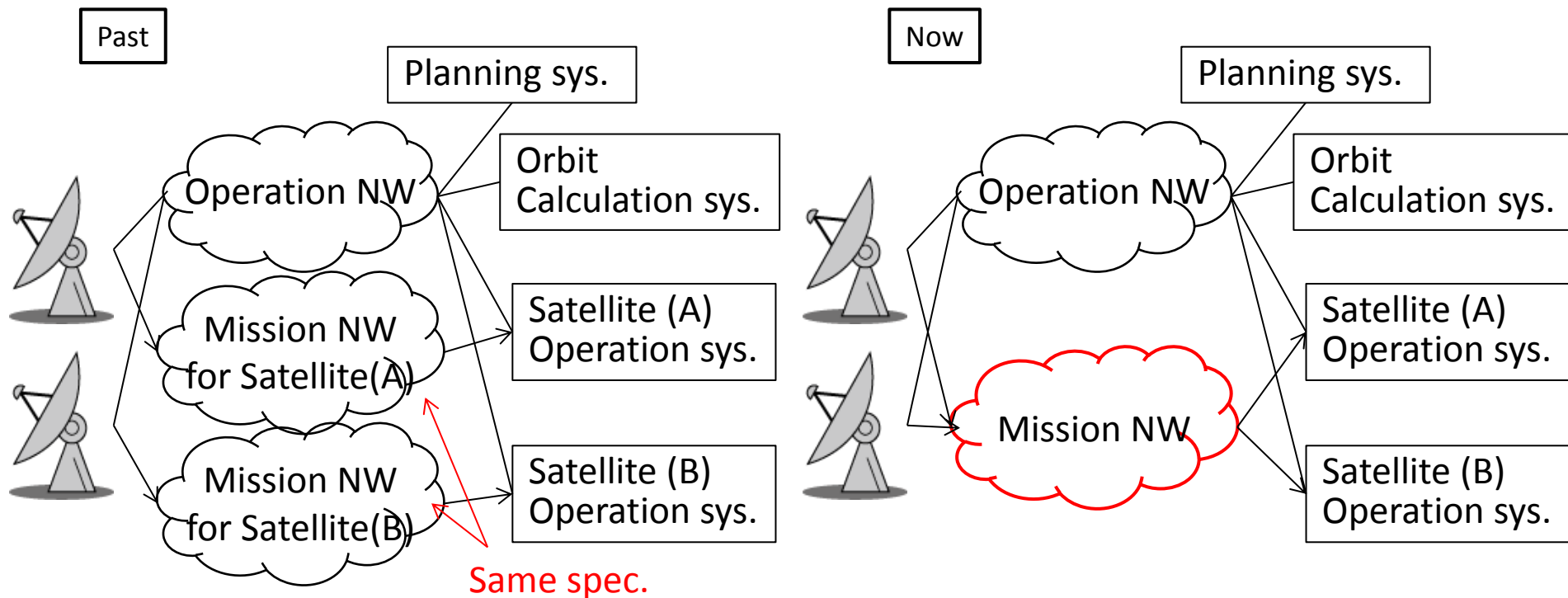




Updates with Data Transmission NW on Ground



- Consisted of an Operation NW and Mission NWs of each satellite
- ↓
- By consolidating mission NWs, each satellite operator share one mission NW
 - Increasing the rate of utilization of mission NW





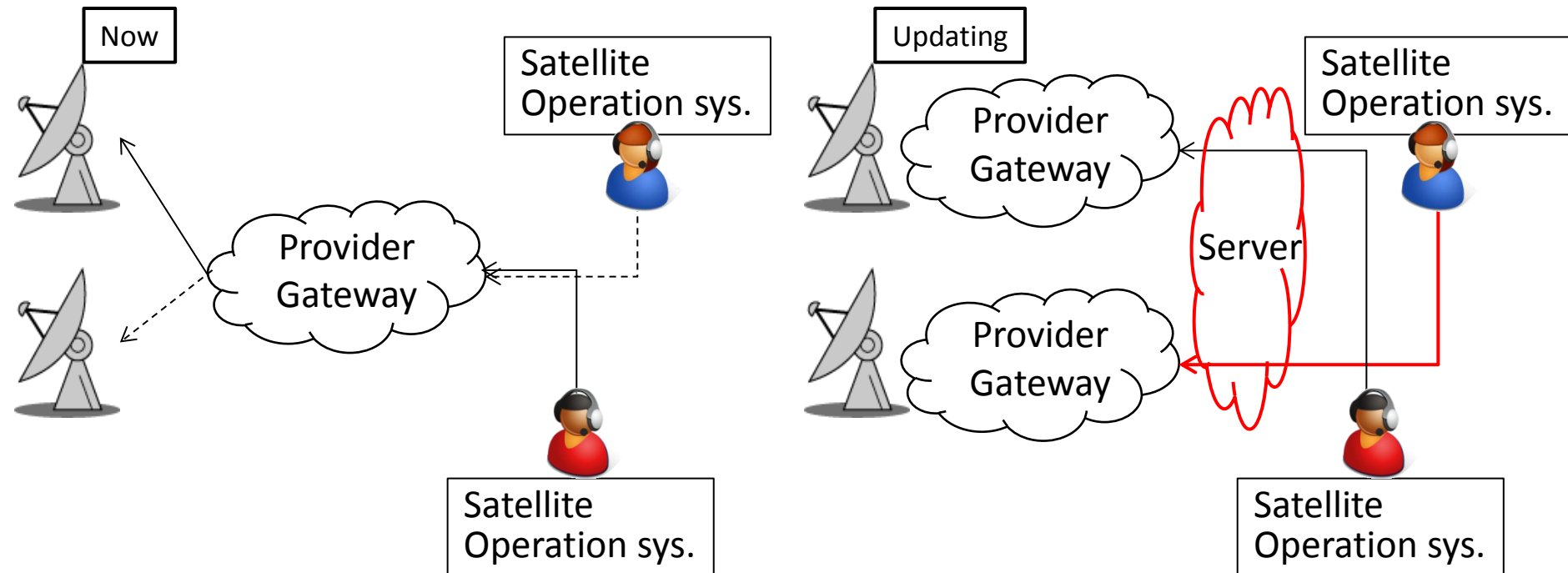
Updating Interoperability



- One-on-one interoperability

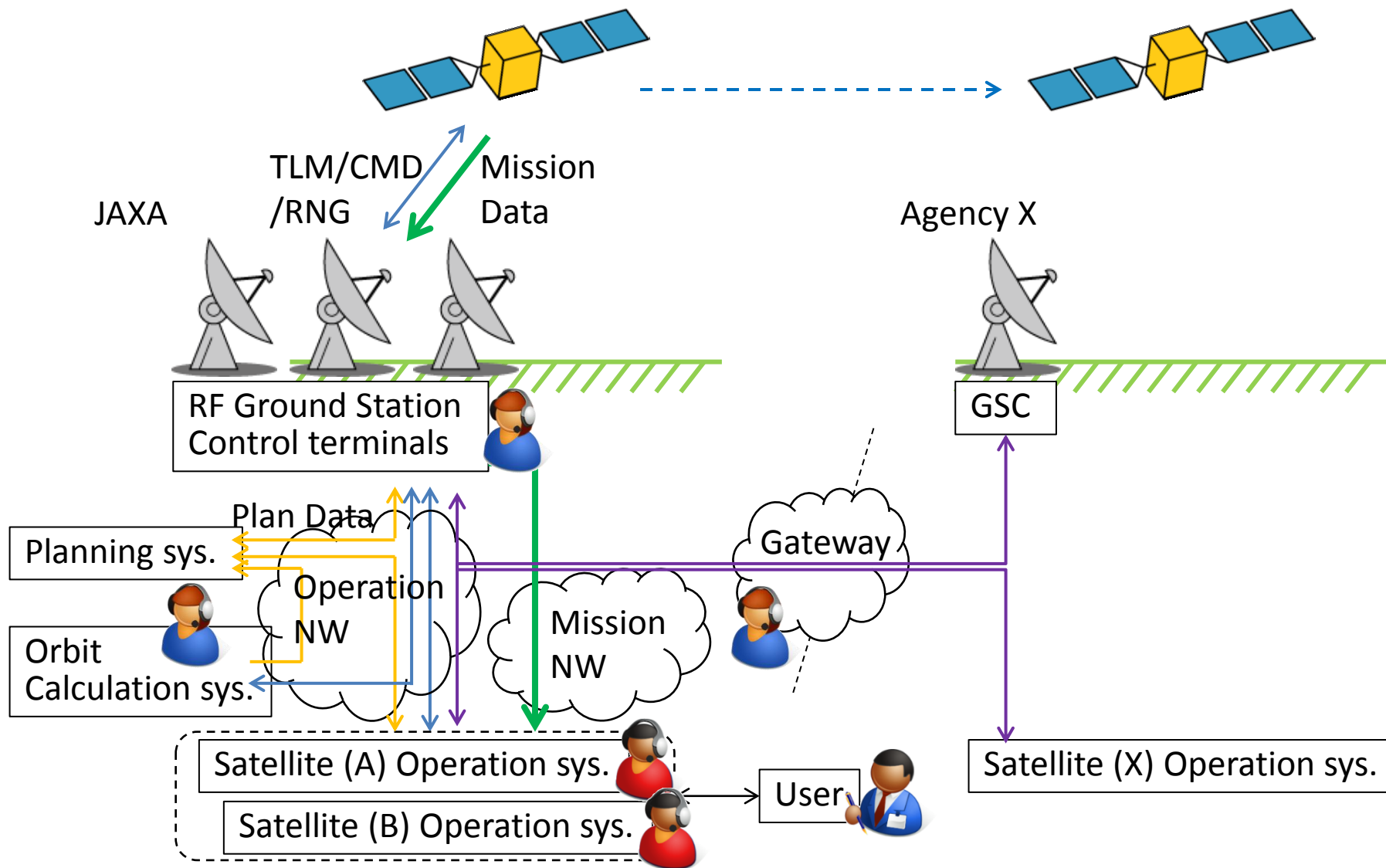


- By setting a provider gateway on each station, each satellite operator can be connected to each ground station
 - Increasing interoperability of satellites at the same time





Summary of Ground System

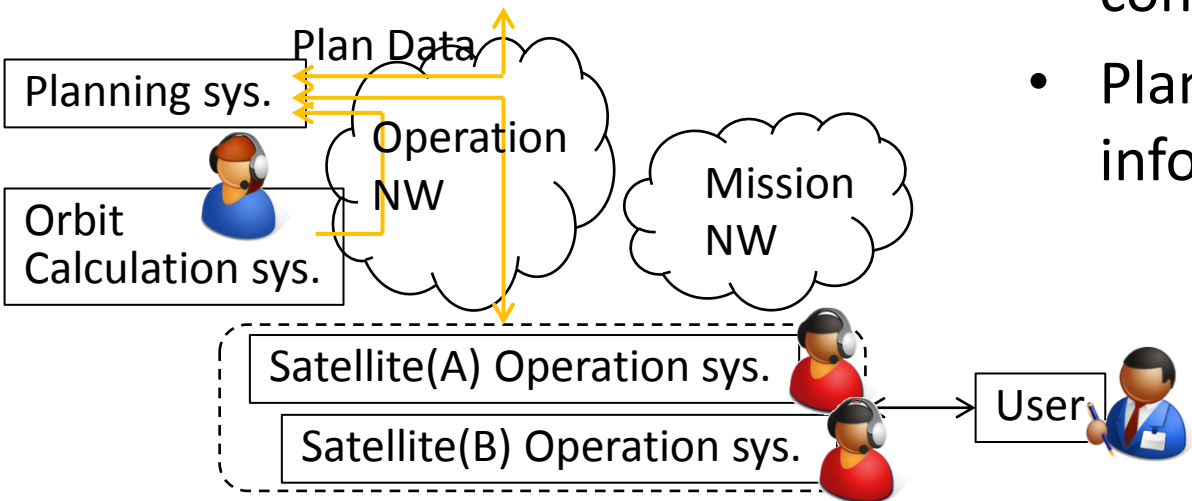




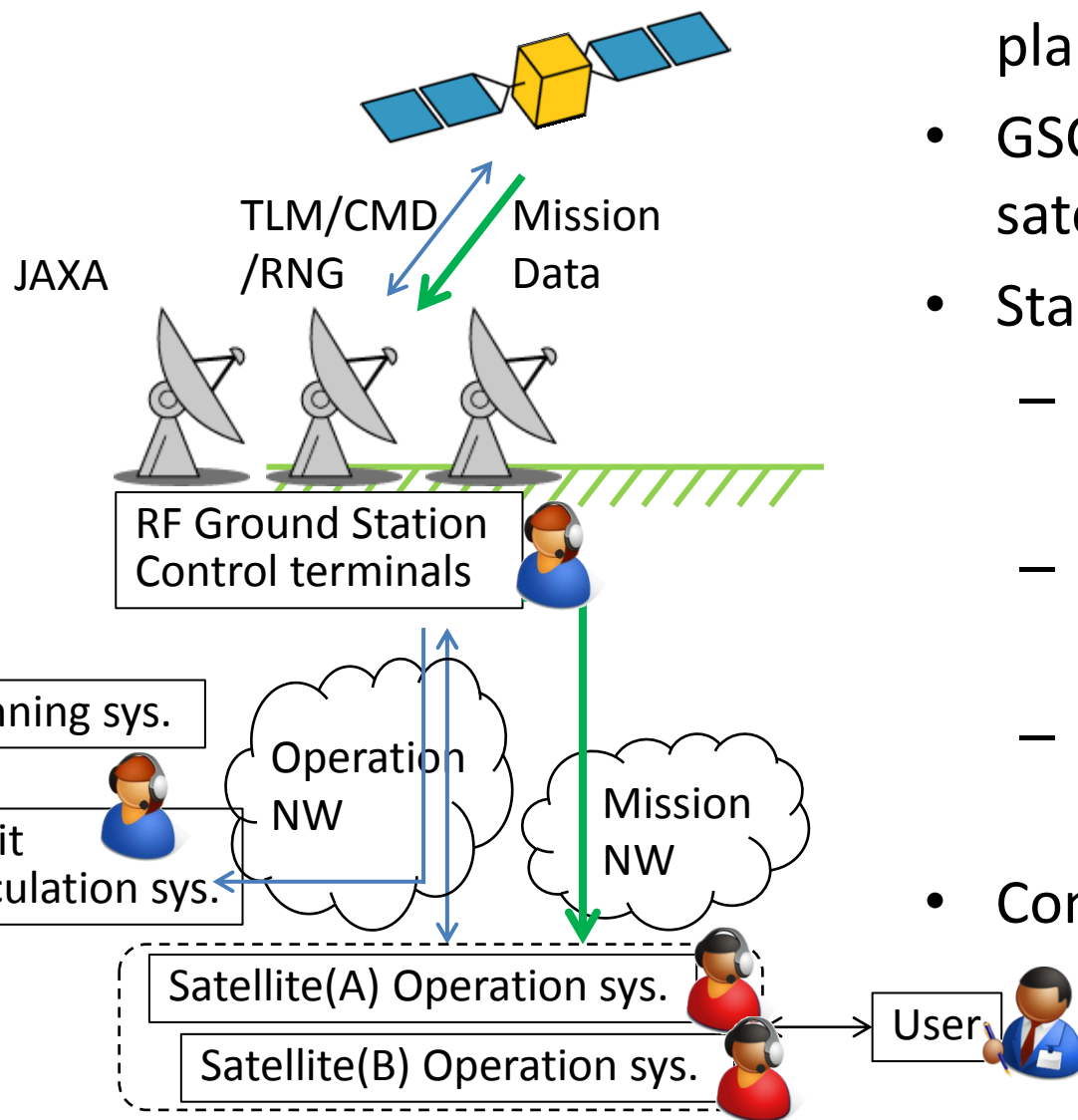
[Ref.] Operation Sequence; Planning Phase



JAXA



- Send visible time information from Orbit Calculation sys. to Planning sys.
- Each satellite operator reserves ground station(s)
- Planning sys. coordinates each reservation and confirms the plan
- Planning sys. sends the plan information to GSC



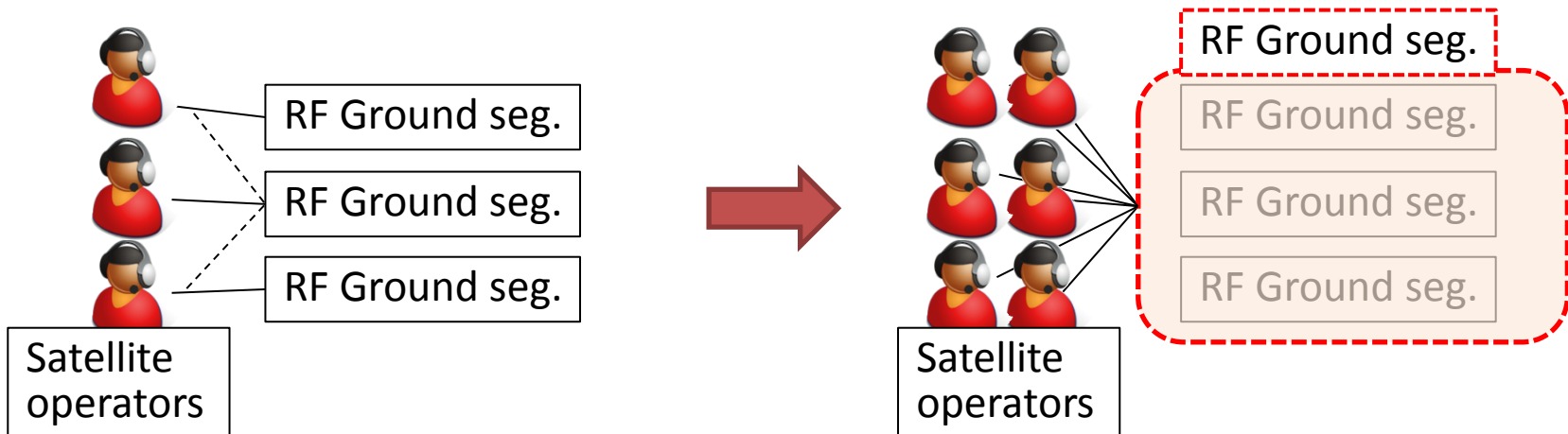
- Start operation according to plan information
- GSC acquires and tracks a satellite
- Start communication
 - CMD sent from Satellite operation sys.
 - TLM and Mission data sent to Satellite operation sys.
 - RNG sent to Orbit Calculation sys.
- Complete the operation according to the plan information



Past Update for Ground Segment



- 1st step : Developed individual ground segment for each mission
 - Without developing prototype ground station
 - Acquired operation knowledge in each mission
- 2nd step : Consolidated individual ground segments for more efficiency
 - Improved convenience for satellite operators
 - Decreased running cost





How should optical station be developed?

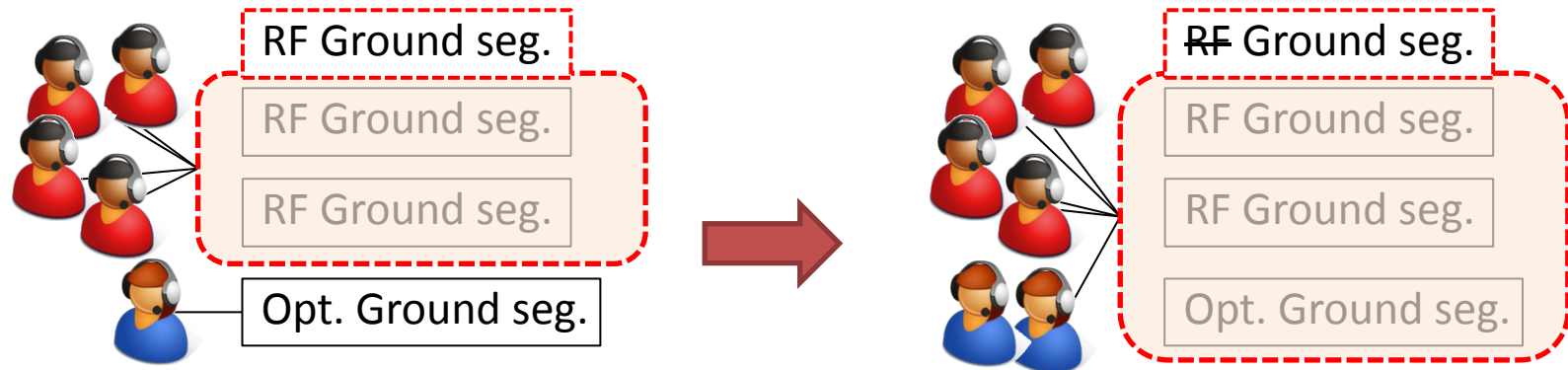


- A) Developing step by step
 - First, optical station will be developed independently

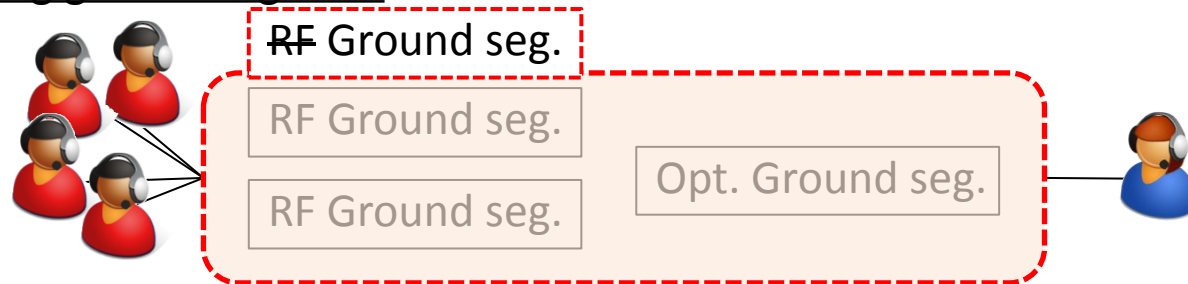
- B) Using existing ground segment
 - To pull in initial cost and running cost

(e.g. Mission NW, Planning sys.)

Developing step by step



Using existing ground segment

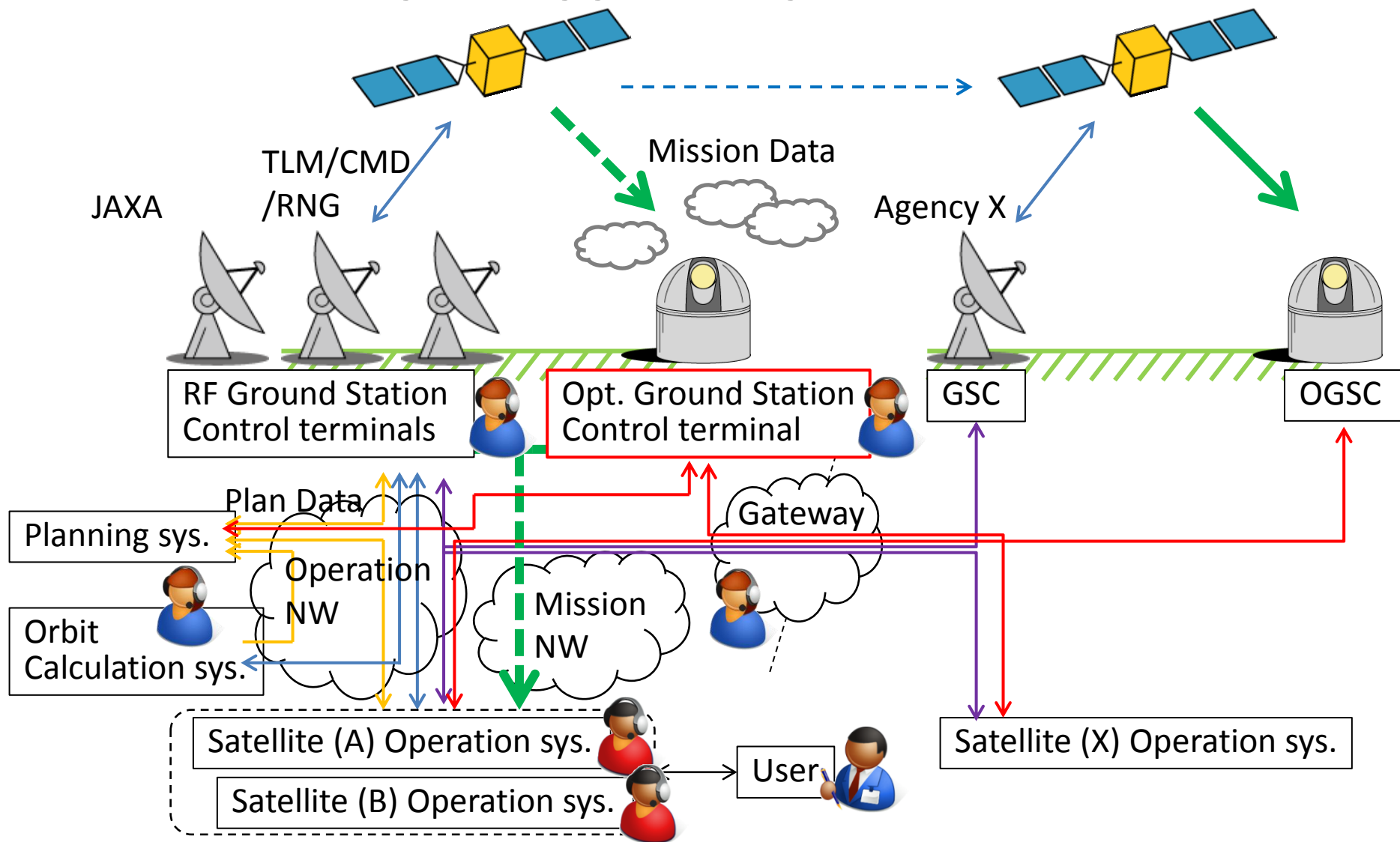




A Future Ground System



- Consider using existing ground segment



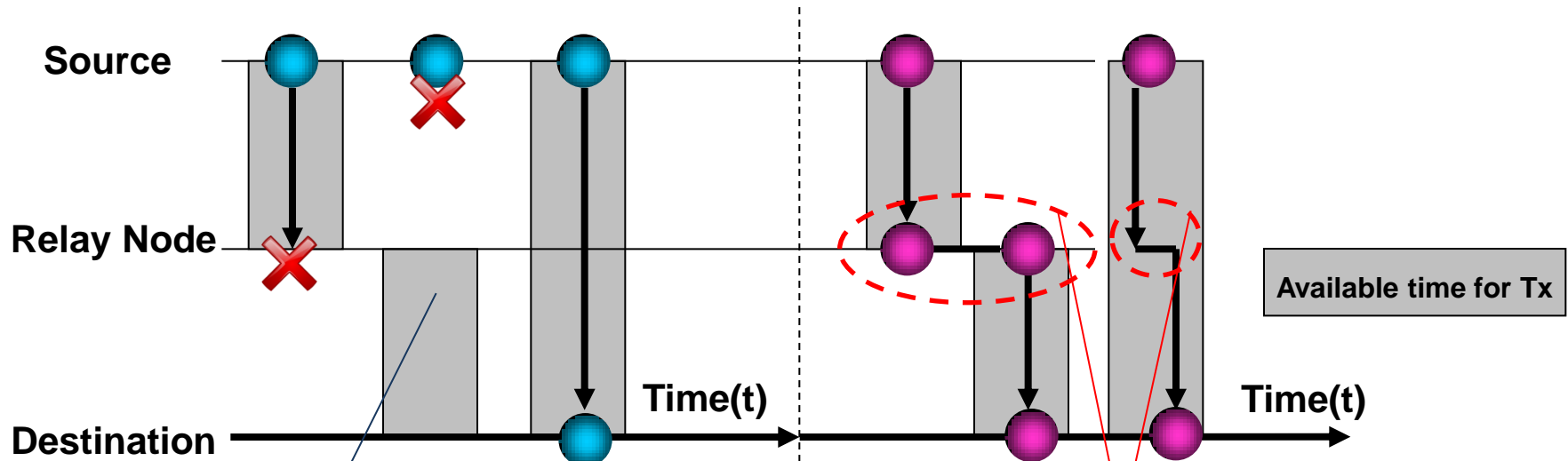


- Communication link disruption tends to occur being affected by meteorological phenomenon
 - Applying automatic repeat mechanism (a theme in OLSG)
 - Updating planning system to deal with meteorological data (a theme in OLSG)
- Transmitting large file on the interoperable NW in case of cross-support



A Countermeasure

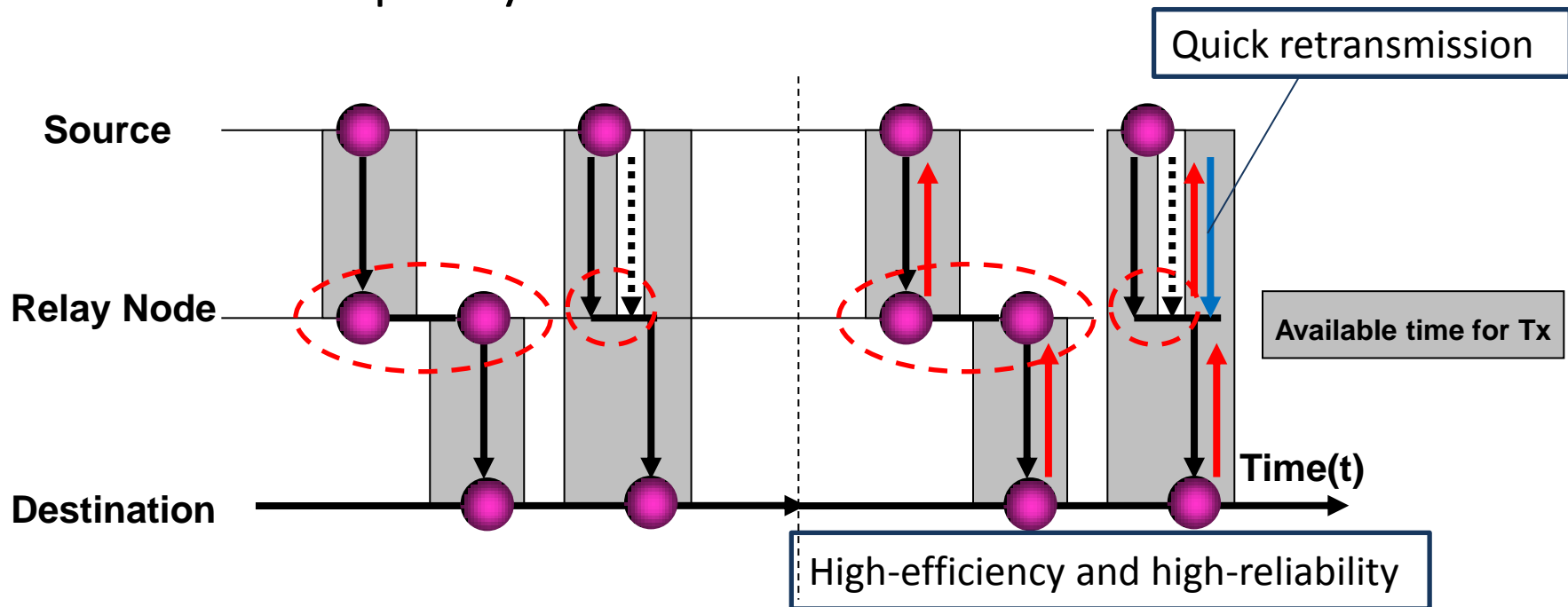
- Considering Disruption Tolerant Networking (DTN) technology which OLSG focuses on as an automatic repeat technology to be applied to optical link
- Feature of DTN
 - Avoids to lose data by Store & Forward transmission under a disruption circumstance



Data transmission not completed if there is disruption between source and destination



- For applying high-efficiency and high-reliability DTN protocol, use acknowledges to satellites
- To introduce an ACK sending mechanism, What link do we use?
 - Optical Link
 - Radio Frequency Link

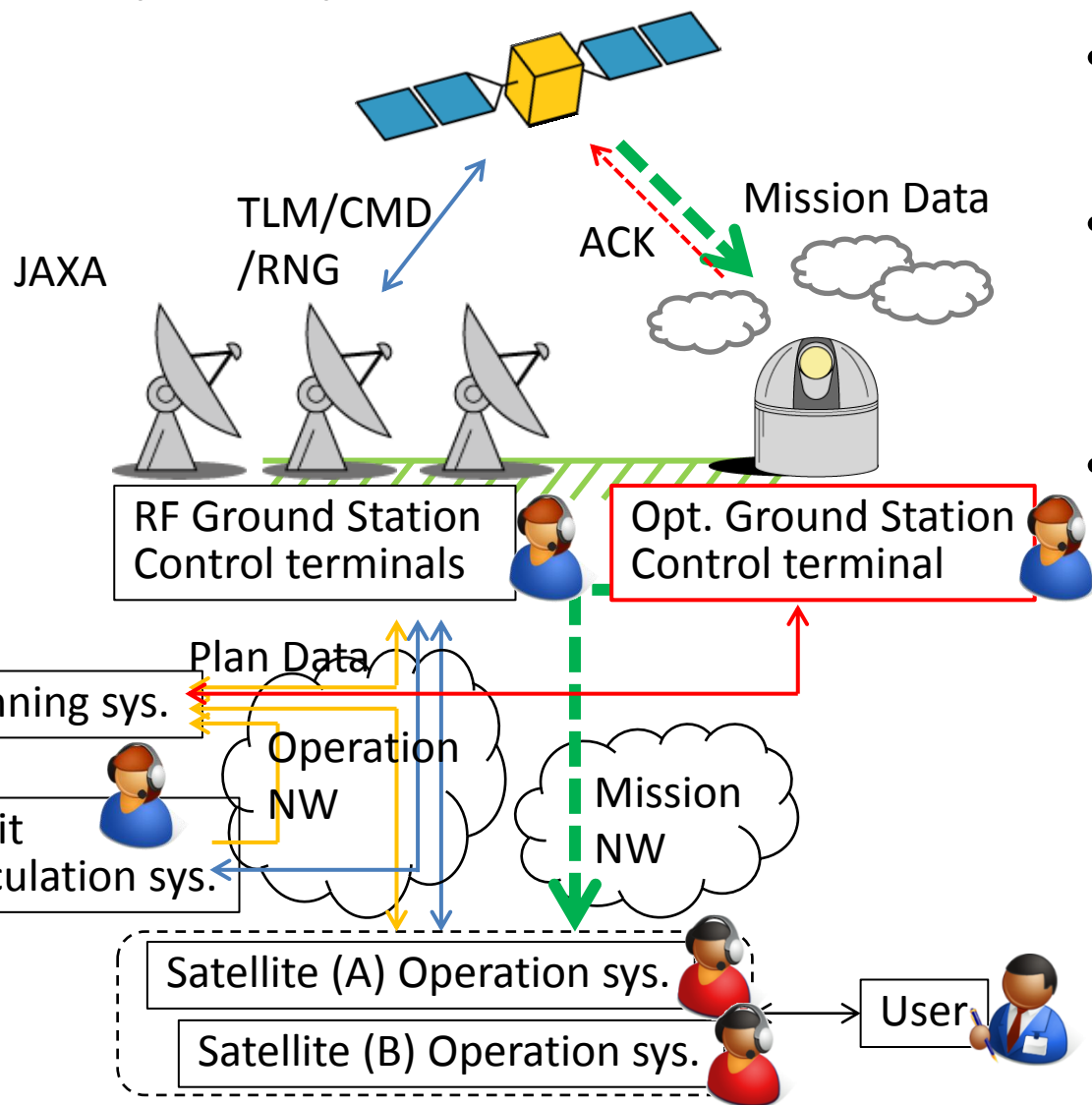




Optical Link with DTN (1/2)



A) Optical uplink case



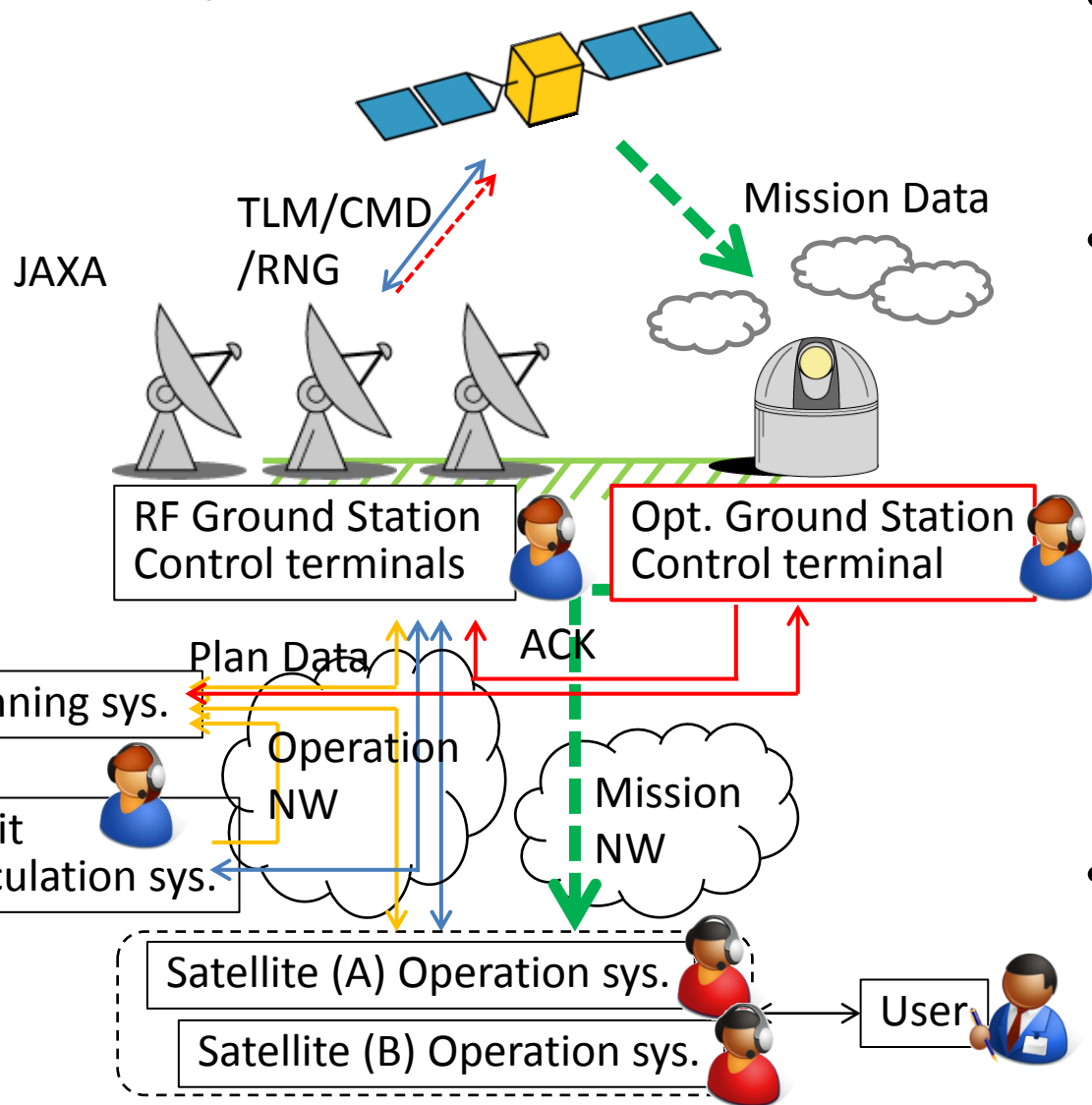
- Need bidirectional communication
- Separate Optical station NW from RF station
- Concerning issue of eye-safety by uplink beam,
 - Use high photon flux optical link in case of long communication distance



Optical Link with DTN (2/2)



B) RF uplink case



- Bidirectional communication not required
- Connect between Optical station NW and RF station
 - It is better that Opt. station and RF station have links to the satellite at the same time
- Mitigate the issue of eye-safety by uplink beam



A) Optical uplink cases

- Taking advantage of Near Earth missions (e.g. LEO)
 - More simple for cross-support since using optical station only
 - Easier to avoid the issue of eye-safety due to less photon flux

B) RF uplink cases

- Taking advantage of far-GO missions (e.g. moon, L2)
 - More difficult to avoid the issue of eye-safety due to increasing photon flux
 - Becoming easier that Opt. station and RF station have links to a satellite at the same time because of far distance



- Introduced activities with optical link in Japan
- Discuss the following
 - Upgrade for adding optical ground station to the existing ground segment
 - Applying new technology for Optical Link