

# Introduction of Open Platform Concept for Global Ground Station Network

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# Japanese University activities



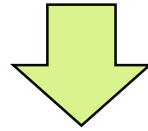
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[http://unisec.jp/wp/wp-content/uploads/2016/06/UNISEC\\_Satellites\\_160120\\_JP\\_s.jpg](http://unisec.jp/wp/wp-content/uploads/2016/06/UNISEC_Satellites_160120_JP_s.jpg)

# Japanese University activities



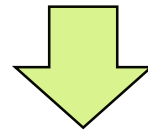
After satellite BUS technology development, after technology demonstration finished.



**What do we do next?**

**How do we get research budget?**

**How can we create sustainable space application?**



**Most of next satellite mission require satellite constellation.**

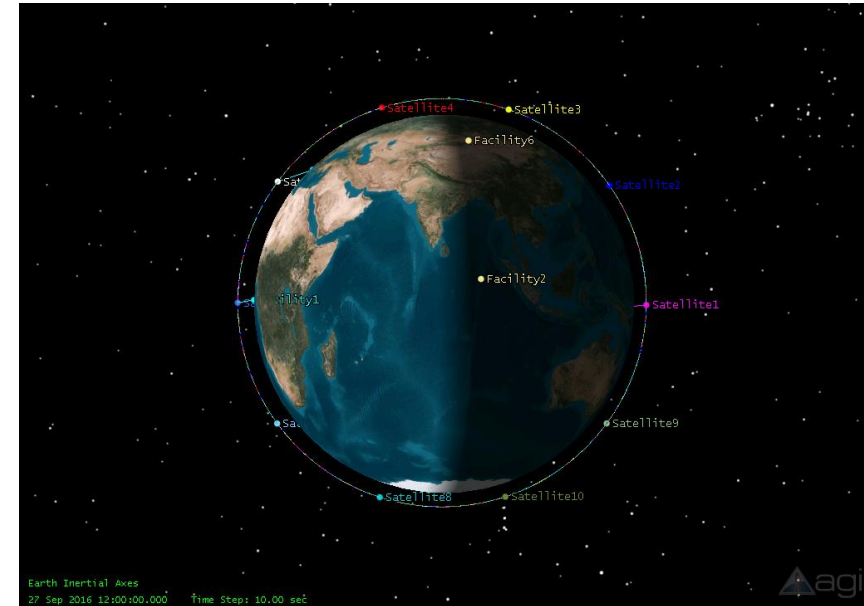
**How do we operate 10s/100s satellites?**

- Simple analysis of ground station number requirement
- Introduction of new satellite operation platform concept
- Conclusion

# Analysis of Pass Overlap (1/2)

- Simplified analysis for Polar Earth Orbit and 10 satellites distributed one orbital surface (36 deg separation)
- Orbit and ground station parameters

| Orbit Parameter     | Value  |
|---------------------|--------|
| Apogee Altitude     | 600 km |
| Perigee Altitude    | 600 km |
| Inclination         | 98 deg |
| Argument of Perigee | 0 deg  |
| RAAN                | 0 deg  |

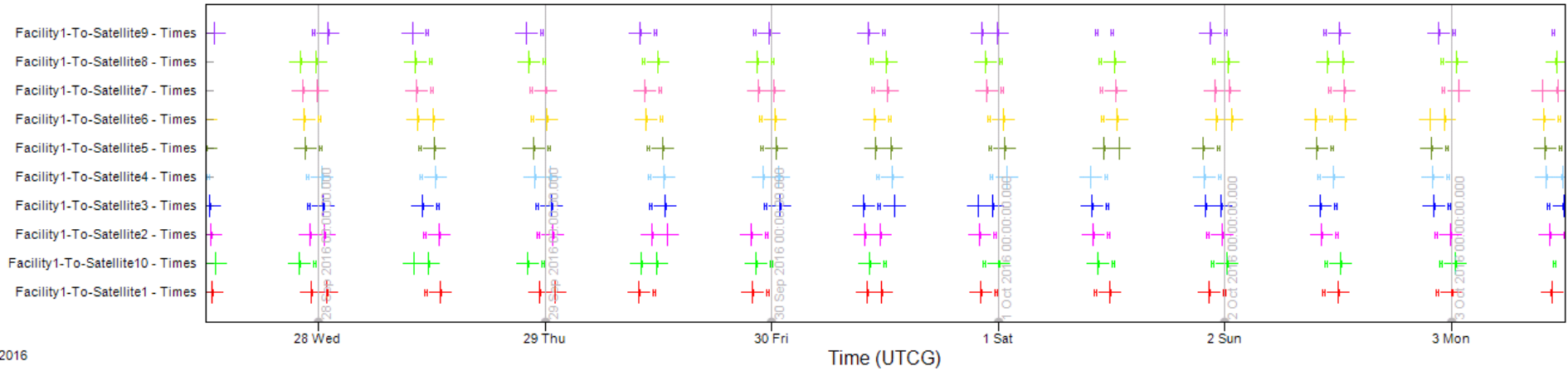


|                  | Ground Station Location   |
|------------------|---|
| Ground Station A | Latitude: 0 deg, Longitude: 0 deg<br>Altitude Reference: WGS84  |
| Ground Station B | Latitude: 45 deg, Longitude: 0 deg<br>Altitude Reference: WGS84 |

# Analysis of Pass Overlap (2/2)

## Ground Station A (Equator)

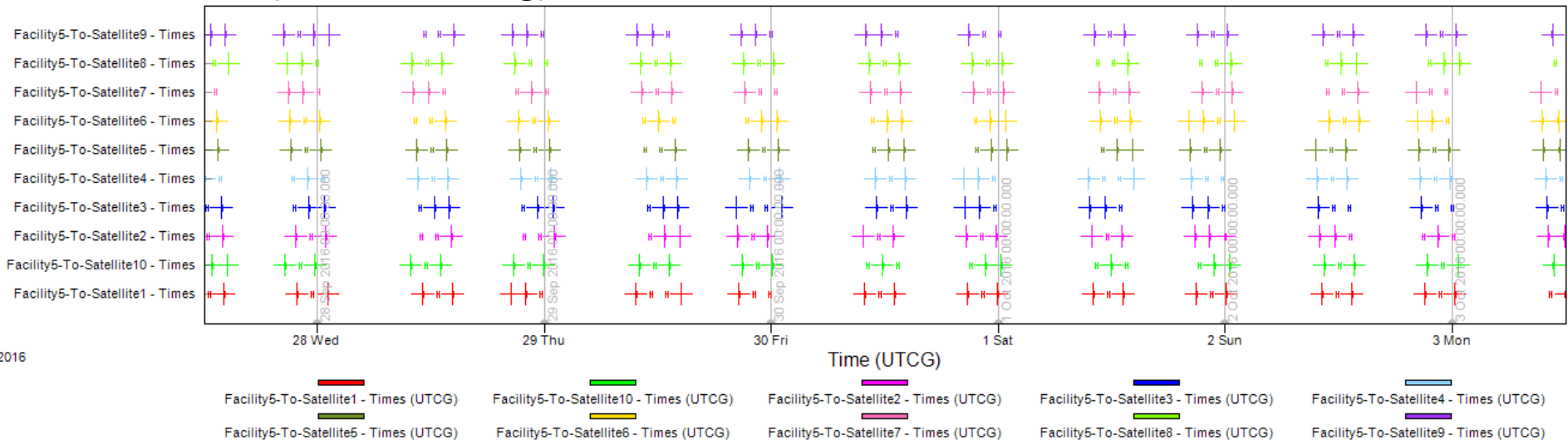
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Passes are overlapped for satellites on same orbital surface

## Ground Station B (Latitude 45 deg)

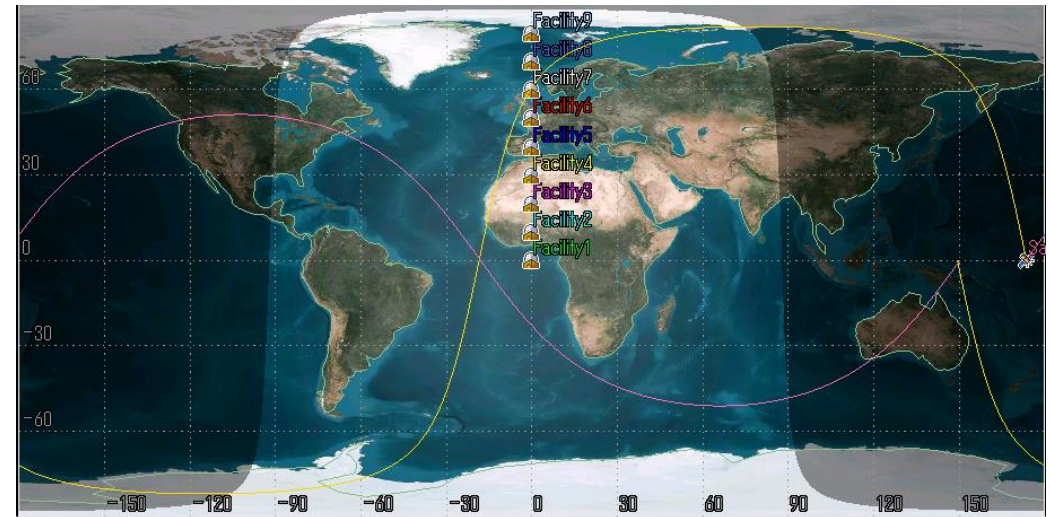
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# Analysis of Pass Duration (1/2)

- 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<br>Longitude: 0 deg<br>Altitude Reference: WGS84 |



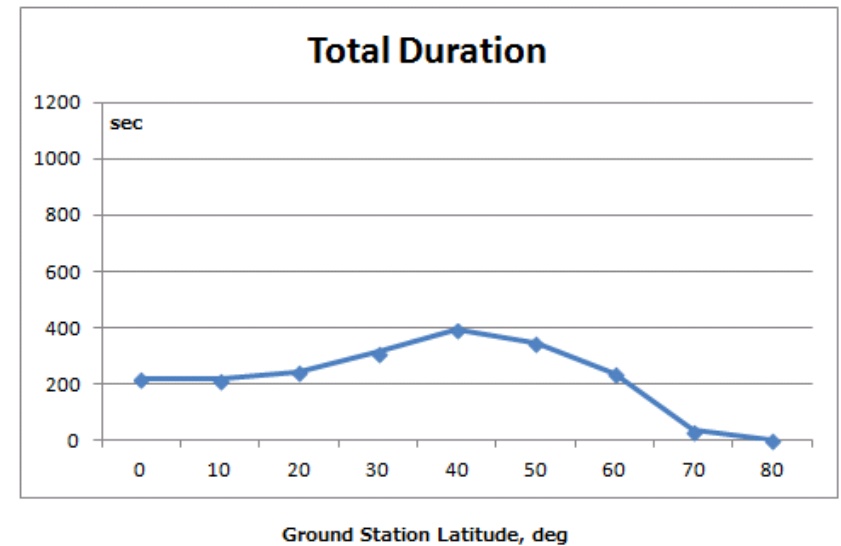
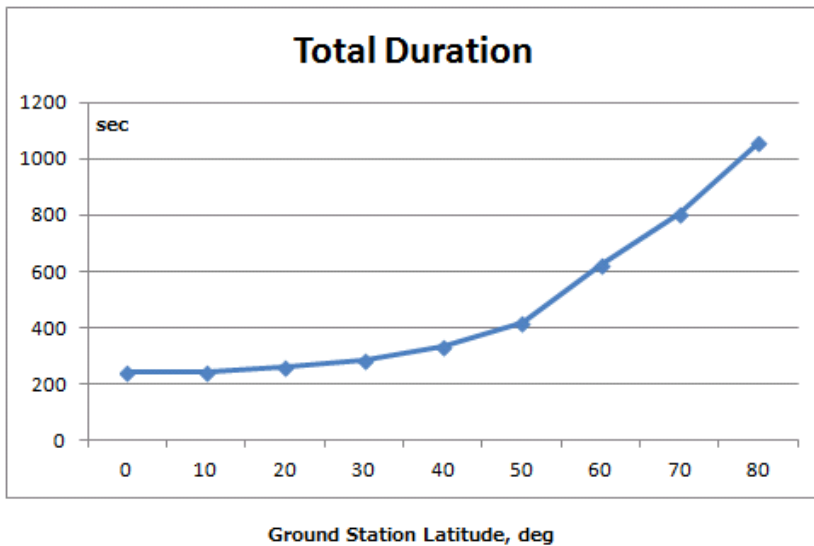
# Analysis of Pass Duration (2/2)

## 600km, 98 deg Inclination

| Latitude (deg) | Number of Pass/Week | Total Pass Duration/Week (min) | Average Pass Duration/Day (min) |
|----------------|---------------------|--------------------------------|---------------------------------|
| 80             | 90                  | 1056                           | 150                             |
| 70             | 74                  | 807                            | 115                             |
| 60             | 64                  | 625                            | 89                              |
| 50             | 42                  | 417                            | 59                              |
| 40             | 33                  | 331                            | 47                              |
| 30             | 29                  | 286                            | 40                              |
| 20             | 26                  | 262                            | 37                              |
| 10             | 24                  | 245                            | 35                              |
| 0              | 24                  | 240                            | 34                              |

## 400km, 51 deg Inclination

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



# Ground Station Number Requirement

The number of required ground station for a given constellation is roughly estimated based on the above discussion.

$$N_{\max} \times T_{\text{op}} = N_{\text{lat1}} \times T_{\text{GS1}} + N_{\text{lat2}} \times T_{\text{GS2}} + \dots + N_{\text{latn}} \times T_{\text{GSn}}$$

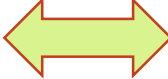
- Maximum number of satellites in an orbital plane,  $N_{\max}$
- Required pass duration per day for operation,  $T_{\text{op}}$
- Number of ground stations at n degree latitude,  $N_{\text{latn}}$
- Average pass duration for ground stations at n degree latitude,  $T_{\text{GSn}}$

Number of required ground station:

$$N_{\text{R}} = N_{\text{lat1}} + N_{\text{lat2}} + \dots + N_{\text{latn}}$$

- There is high possibility of pass overlap for constellation operation.
- Non-constellation operation


Number of ground station      Total communication duration



linear

- For constellation

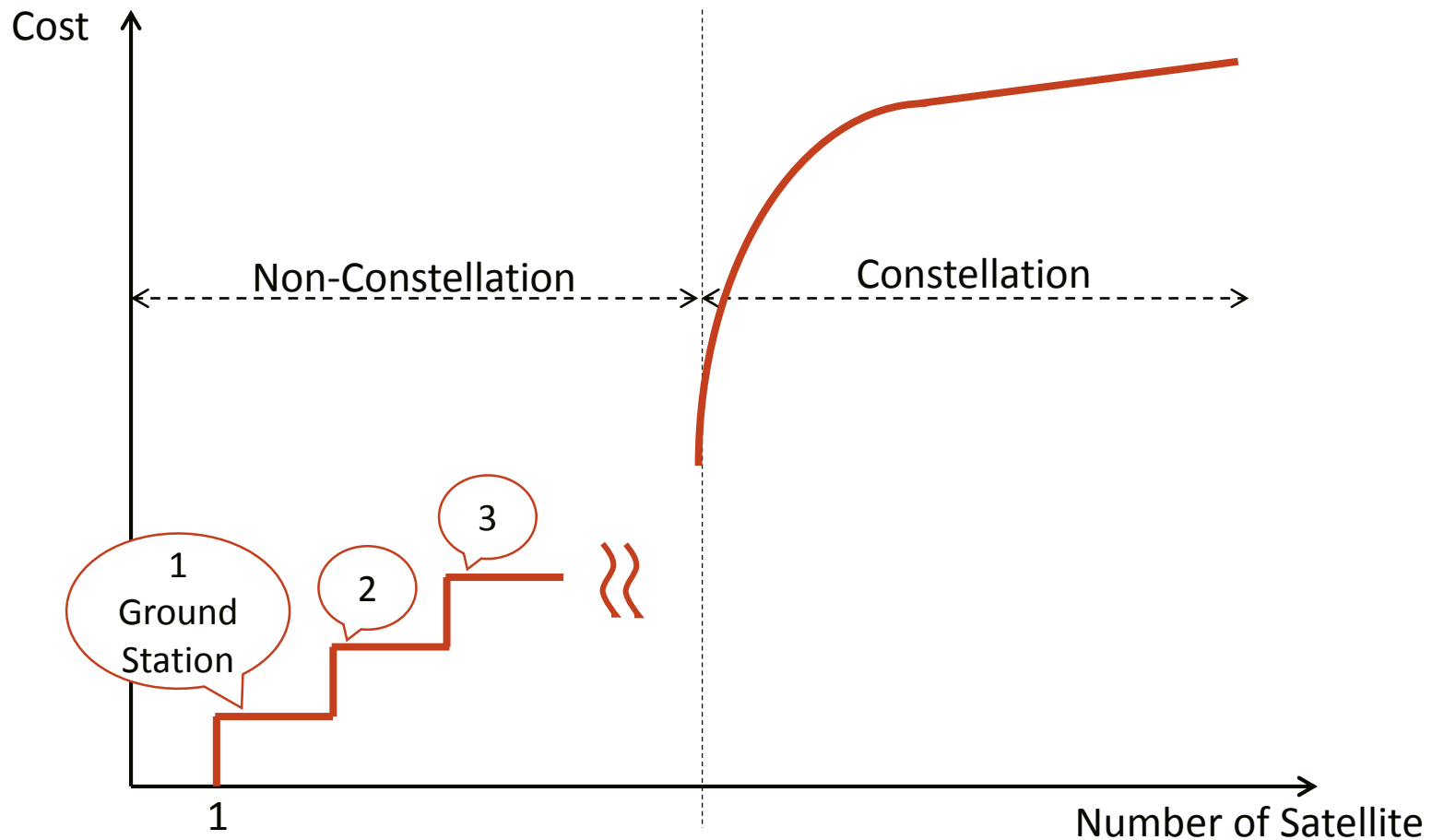
Number of ground station      Total communication duration



Not linear

# Ground System Cost (CAPEX/OPEX)

Ground system cost doesn't increase linearly.



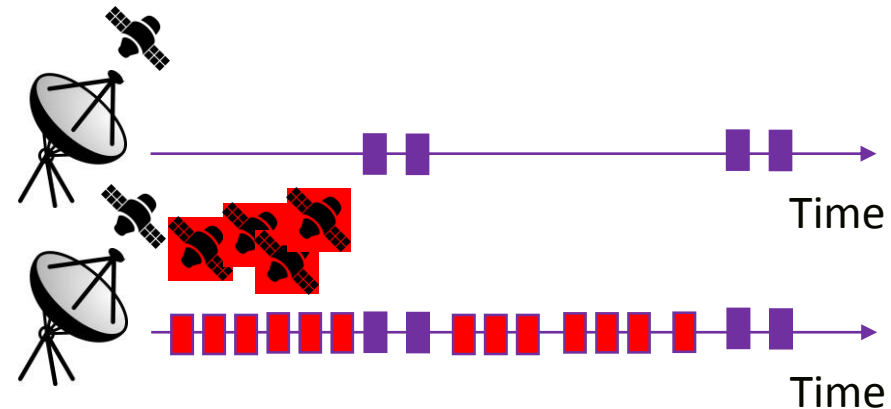
# Satellite Pass Cost



| Type              | Initial Cost, USD              | Power+Internet Cost/month, USD | Initial + Running Cost/5 years, USD | Pass/day | Pass/5 years | Cost/pass, USD |
|-------------------|--------------------------------|--------------------------------|-------------------------------------|----------|--------------|----------------|
| Yagi              | 10,000                         | 600                            | 10,000 + 36,000<br>= 46,000         | 5        | 9125         | 5 <            |
|                   |                                | 600                            | 10,000 + 36,000<br>= 46,000         | 12       | 21,900       | 2 <            |
|                   |                                | 2,000                          | 10,000 + 120,000<br>= 130,000       | 60       | 109500       | 1 <            |
| Dish<br>(2 – 4 m) | 400,000<br>(200,000 – 600,000) | 600                            | 400,000 + 36,000<br>= 436,000       | 5        | 9125         | 48 <           |
|                   |                                | 600                            | 400,000 + 36,000<br>= 436,000       | 12       | 21,900       | 20 <           |
|                   |                                | 2,000                          | 400,000 + 120,000<br>= 520,000      | 60       | 109500       | 5 <            |

Antenna usage increased, satellite pass cost decreased.

- Need ground station network as infrastructure, such as the Internet.
- How to create? → Apply “Sharing Economy” concept

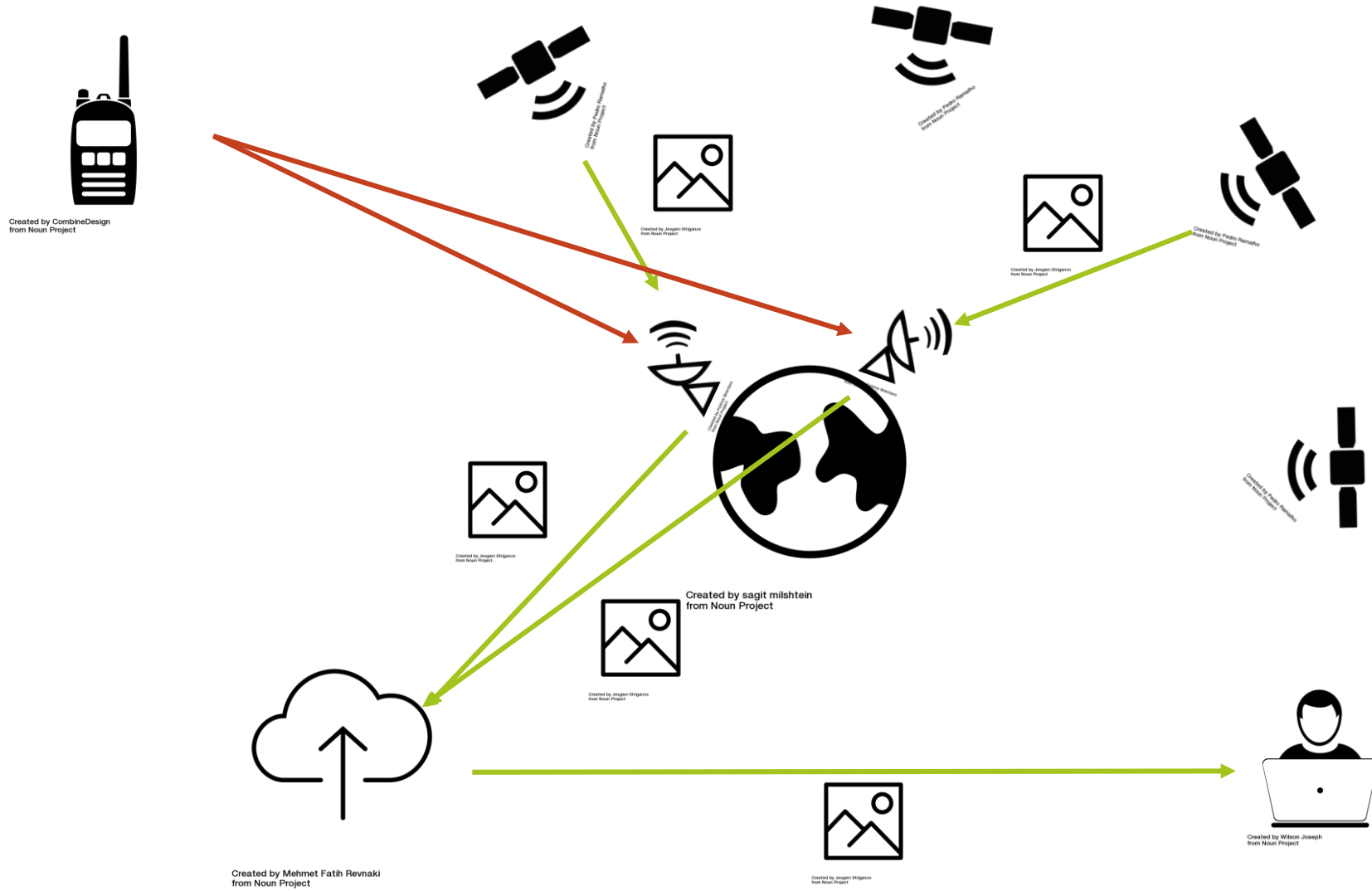


- How to be a sustainable network?

→ Charge for private business. (Running cost)

→ Return free/cheap pass usage for contributor, who share their antenna's idling time. (Network growth)

- Infrastructure of satellite operation is needed to realize next satellite constellation application
- Antenna sharing-economy system for satellite operation is proposed to create the infrastructure.



Provide connections between antenna-ground server-satellite operator



22<sup>nd</sup> October, 2016

Group Discussion Session

Group 5:

Collaborators meeting for new ground station network experiment

Thank you.



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