<SACULA> project

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Project member

Our project group consists of

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8 graduate students

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1 adviser

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Mean of our project <SACULA>

SACULA stands for...

Space demonstration of Autonomous assembled CUbesats for Large size Architecture

<SACULA> (sakura) is
also related to cherry blossom
Cherry blossom is very popular flower in Japan

Many small flowers bloom beautifully on a cherry tree like a modular structured SPS

Back Ground

There are some problems to realize SPS

1. **Power Generation system**

   Improvement of power generation efficiency, Weight saving & film−thinning of solar cell

2. **Power transmission system**

   Long distance power transmission, High efficiency transmission as power plant

3. **Large structure**

   Construction of several km^2−class structure, Attitude control, Shape keeping

4. **Durability for space environment**

   Countermeasure for space debris, Design to minimize influence of radiation hardness

5. **Mass transportation**

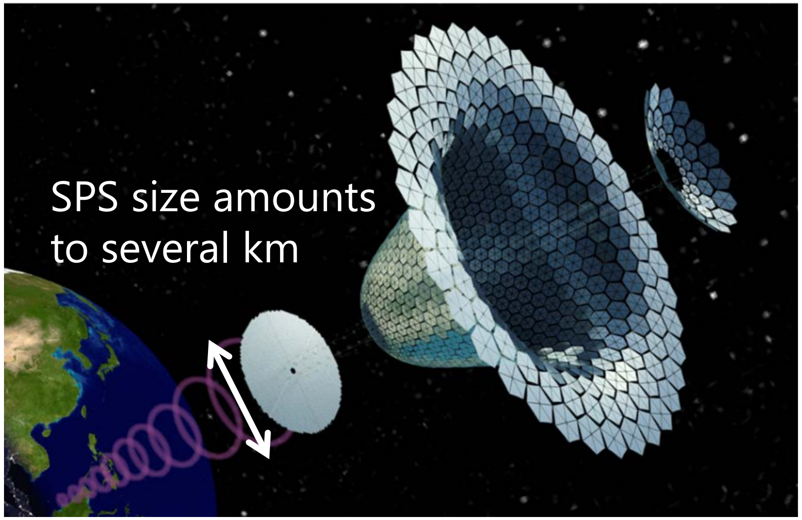
   Cost reduction of rocket launch, Weight saving of satellite

We focus on **3**) Large structure

Why we focus on structure

Large structure is basis to realize SPS

- SPS needs Large area to generate GW-class power
- Large phased array antennas are need for high efficiency power transmission



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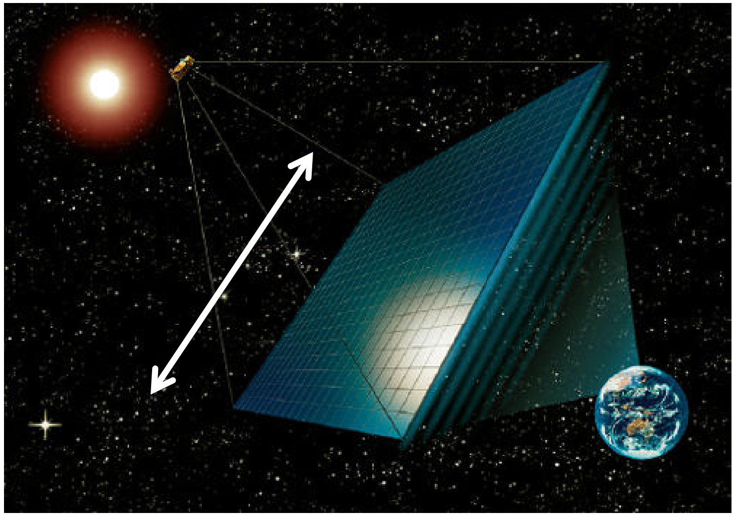
SPS-α



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Tethered SPS

Key technologies

We can not carry km-sized structure
by single launch of rocket

	Falcon heavy	Delta Ⅳ heavy	H3
Faring height	13.9m	19.1m	16m
Faring diameter	5.2m	5.1m	5.2m
Payload to LEO	54,400 kg	28,790 kg	-
Payload to GTO	22,200 kg	14,220 kg	6,500kg

Payload fairing has a limit…

- Mass transportation
- Weight saving as much as possible

Modular structure
&
Deployment mechanics
are key technologies
to construct large architecture

Concept of our project

We will make a step to space infrastructure

Now, the largest structure is ISS —approximately 100m

Novel technology is necessary to construct km-sized space structure like SPS because it requires simple system & low cost for their module

Nobody have ever launched, deployed and connected a lot of small pieces in space to construct large structure
We would like to do that

Our project aim to be a first step of
km-scale space infrastructure construction

Purpose of our project

1. Studying construction of
   large-scale space infrastructure
   that is adopted modular concept toward SPS

2. Planning the preliminary
   space demonstration on our concept

Goal of our project

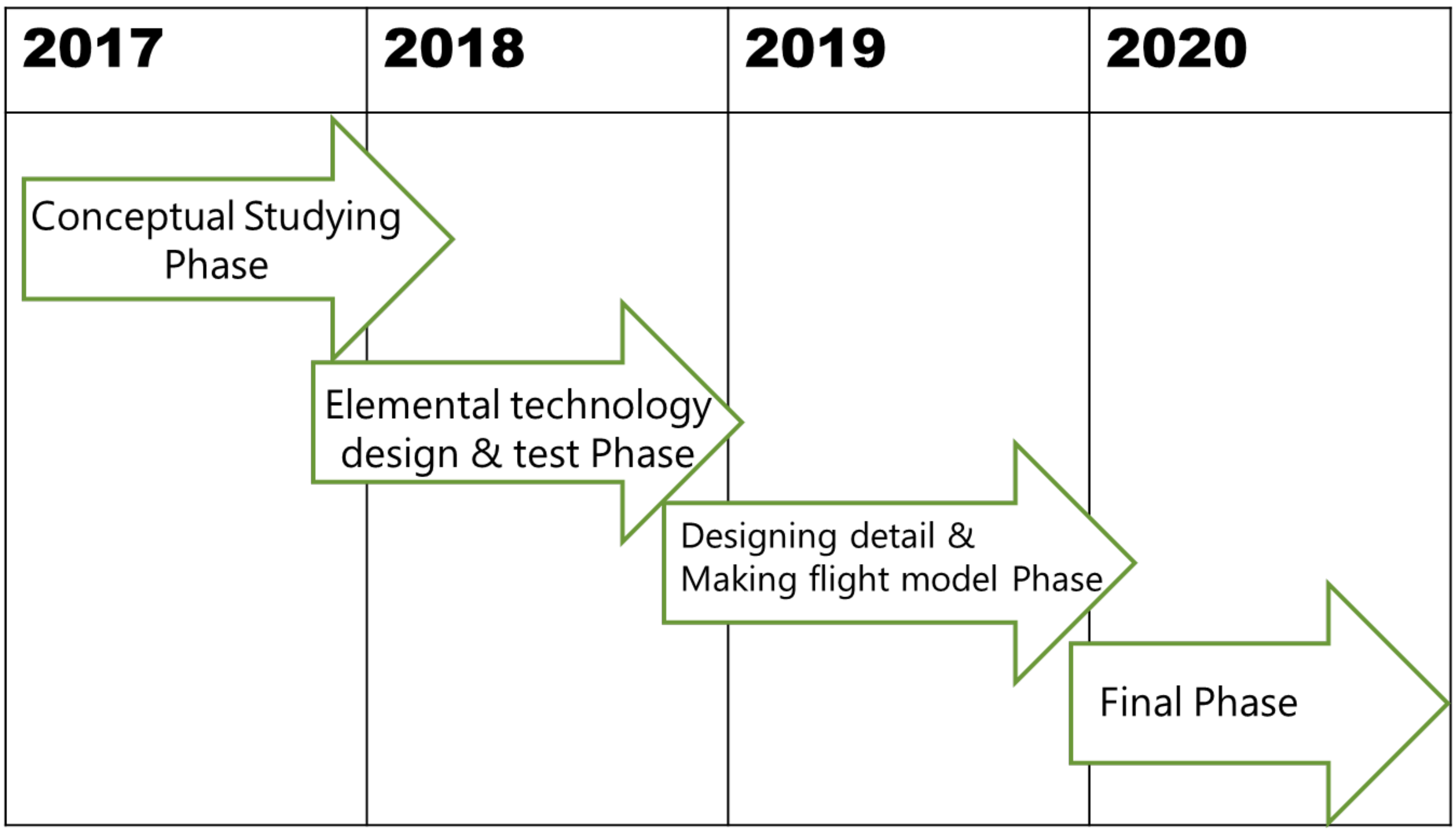
1. We would like to study & develop a method to construct large-scale space infrastructure by modules

2. We would like to demonstrate construction large scale structure toward SPS by using deployable modular systems
   &
   principle of power generation and transmission

We aim to carry out this demonstration in connection with the Tokyo Olympic 2020

Project schedule

There are 4 phases in our project from 2017 to 2020



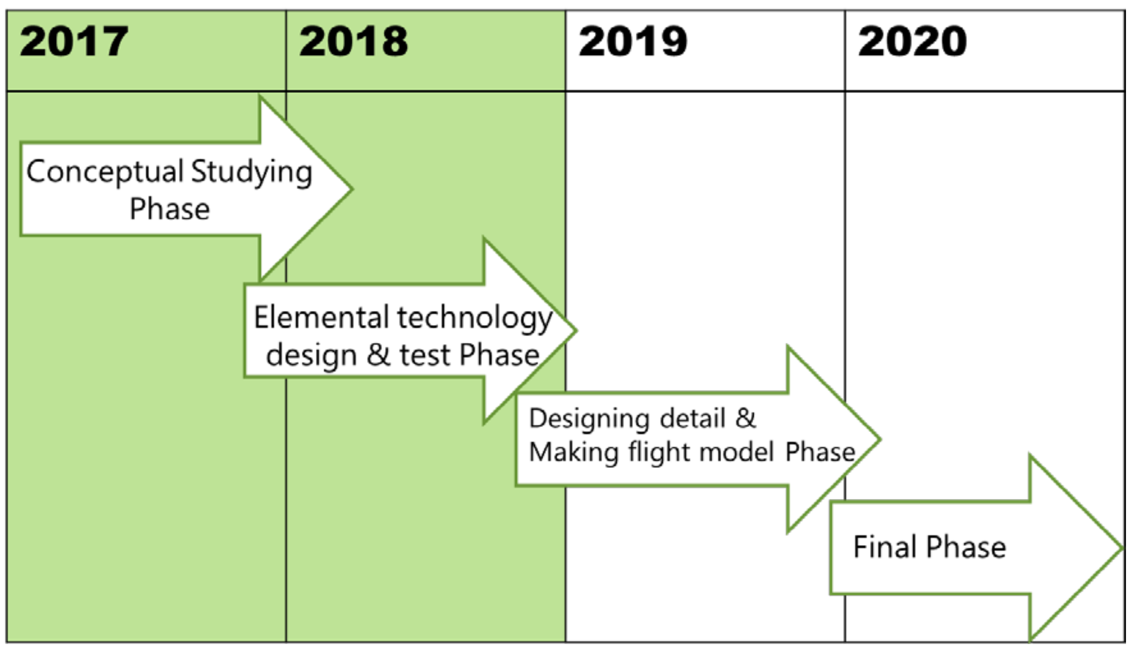
Schedule of 2017~2018

2017 Conceptual studying phase

Now, we are studying concept of modular structured SPS.
We are planning that this study is central element of our project in 2017

2018 Elemental technology design & test phase

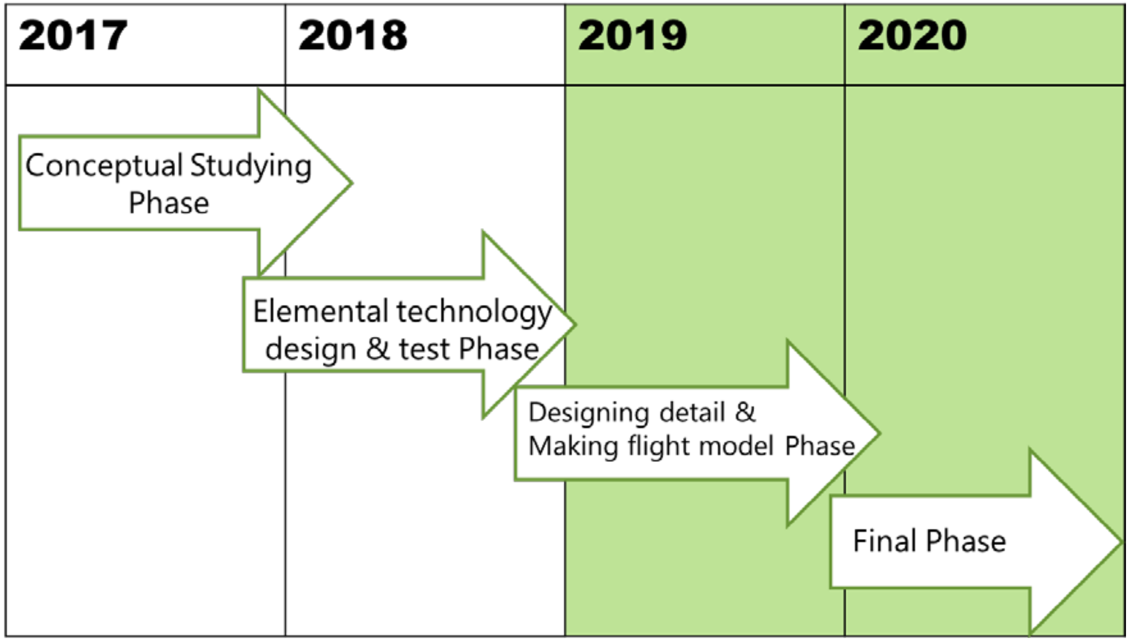
We will design & test elemental technology of our model in 2018



Schedule of 2019~2020

2019 Designing detail & making flight model phase
We will design detail of satellite & start making flight model in 2019
We desire to cooperate with another team and make several CubeSats to construct larger scale structure than made by only one team

2020 Final phase
CubeSat will launch in 2020
We aim to carry out demonstration in connection with Tokyo Olympic



Requirement of structure of SPS

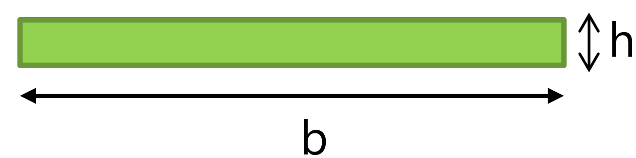
1. **Solar array and Antenna array require large area**
   Generating power is in proportion to solar cell area
   A lot of antenna is necessary for high efficiency power transmission

   →**Earning large area by thin-filmed membrane**

2. **Structure requires stiffness**
   Naturally, stiffness is necessary to keep shape
   Panel's bending stiffness is represented by this formula

$$= EI = E\frac{bh^3}{12}$$

→We have to design structure taking
material & panel's thickness into account
Especially, thickness influent by Third power



E : Young's modulus of material
I : geometrical moment of inertia
b : width of panel
h : thickness of panel

Types of demonstration model

We are considering 3 types of demonstration model

1. Rectangle model

2. Hexagonal model

3. Ring model

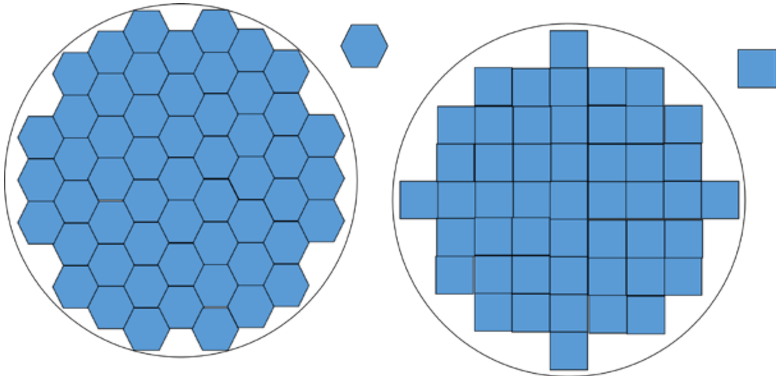
We are also considering their advantage & disadvantage now
They are in a trade-off relation

Rectangle model

2D deploying systems of Rectangle model have been studied in our laboratory.
I would like to show you some examples of them

Deployable hexagonal panels model

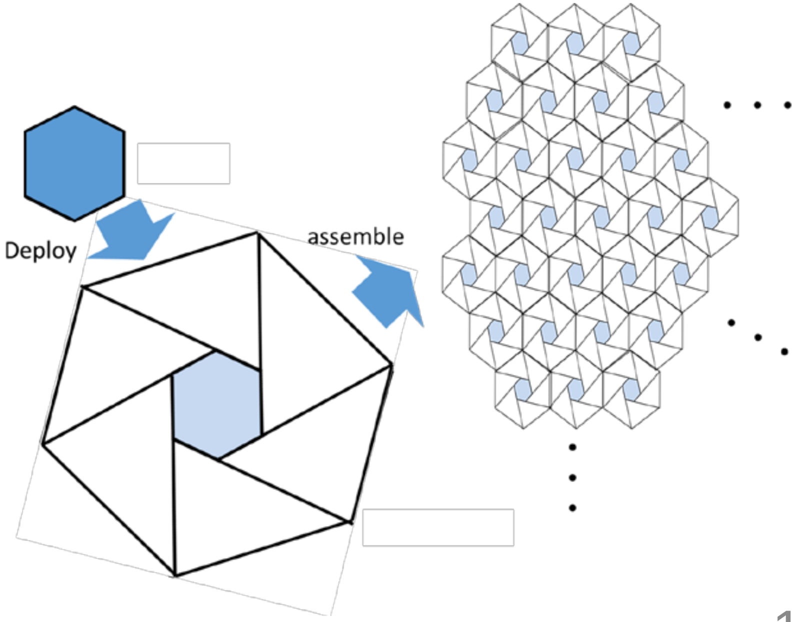
We consider to make SPS's power generation & transmission panel by assembling deployable hexagonal panels



Advantage of hexagon

- Hexagon is the most efficient shape when install cylindrical faring
- Hexagon can make large structure by connecting each other

One of panel is installed Control system, circuit and extensible boom with each 6 side to deploy Thin-film antenna & solar array membrane

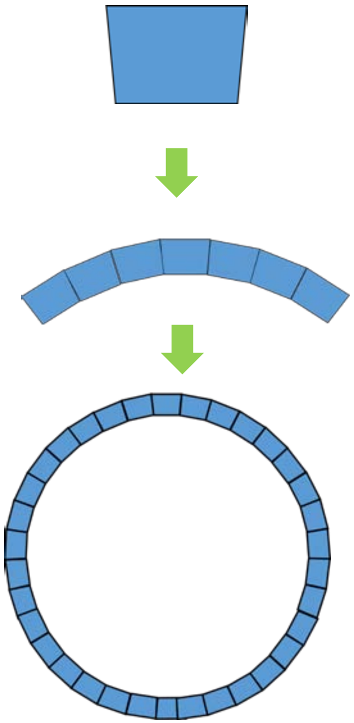


Ring model

- We want to carry out demonstration at a low cost.
  →CubeSat is the most familiar way to do space demonstration

- But, hexagonal panel is not suitable to fill in cubic space
  →Square panel is most suitable

We are considering to construct large ring made by tiny trapezoid, almost square, panels



Advantage of ring
- Ring can be large by less panel
- Systems can be more simple than hexagonal model

Ring model

Ring shape model is presumed as a part of power generation & transmission panel

We can make circle panel by assemble other size rings

Ordering 5 ring shape structures, We can make the Olympic emblem

Outline of demonstration

1. We make small satellite panels
2. Panels are installed to CubeSat
3. CubeSat is transferred to the space
4. Panels deploy & make large structure in space
5. LED installed on panel emit light to the earth
6. We observe it from the ground

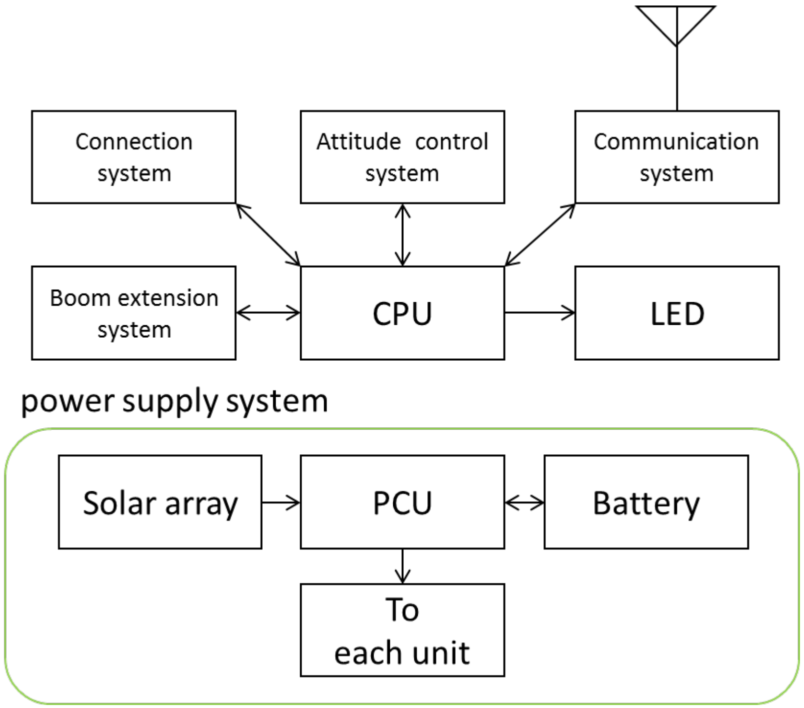
- **Our satellite is constructed with modular structure**
  →It is same as SPS
- **Our satellite generates power by solar cell & emits light**
  →These functions imitate SPS's Power generation & transmission system
- **We observe emitted light from ground**
  →It is substitute for power receiving

Functions of demo satellite

Demonstration satellite requires

- Deployable boom
- Thin film solar sell
- LED
- Attitude control system
- Connection system
- Telecommunications system
- CPU (system control)

etc…



We are researching detail of necessary functions & how archive their request now

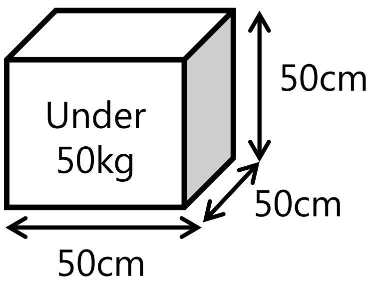
Constraint of demonstration

- Size and mass

  We are thinking a case of using 50×50×50 cm^3 Cube Satellite

  →Volume should be under 125,000 cm^3

  mass should be under 50kg



- Luminosity

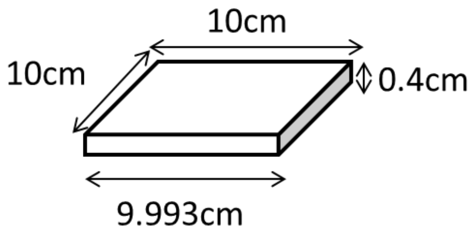
  We are thinking a case of satellite is constructed on 400km height

  → LED need to emit more than 10000cd for observation from ground

Examination of Ring size

We can construct 300m ring in diameter by single Cube satellite launch

Large ring will be made from tiny trapezoid panels that is installed LED and extensible boom to deploy Thin-film solar array membrane.

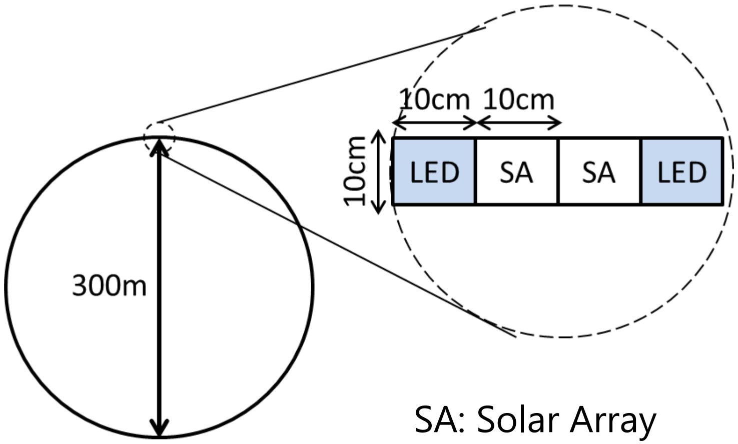


Panel size is presumed as right figure

50*50*50cm3 Cube Satellite
can install 125,000/40 = 3,125panels

If boom extend to 20cm,
circumference amount to
3,125*(10+20) = 93,750cm = 937.5m

Diameter is
937.5/π = 298.41… ≒ **300 m**



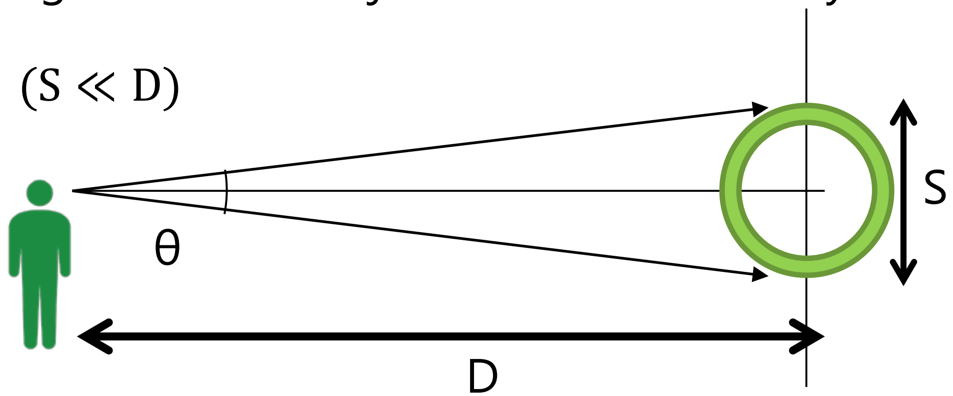
SA: Solar Array

How does look the ring?

Examination of size

Visual angle: the angle a viewed object subtends at the eye

$$\theta = \tan^{-1}\frac{S}{D} \cong \frac{S}{D} \quad (S \ll D)$$



We presume that satellite is on 400km orbit (D=400km, S=300m)

	Visual angle [degree]
Sun	0.532
Moon	0.521
Venus	0.017
300m ring	0.043

300m ring satellite looks approximately 2.6 times larger than Venus (the morning or evening star)

How does look the ring?

Examination of luminosity

Ring's circumference is 937.5m, and panel width is 10cm (0.1m)
Area of ring amounts to

937.5 * 0.1 ≒ **93.8m2**

In case of using thin-film solar cell (conversion efficiency 8.5%)
& presuming that solar energy is 1000W/m2,
solar cell generates

93.8 * 1000 * 0.085 = 7964.5 ≒ **8kW**

Considering 65% of generated power (**5.2kW**) is used for light emission
LED(Cree Inc. : C503C-WAS) can emit 35cd by 120mW
We can use 5.2kW/120mW = 43,333LEDs; they emit 35 * 43333 ≒ **1,500,000cd**

How does look the ring?

Examination of luminosity

Luminosity can be calculated into luminance (E) [cd/m2]
We presume that satellite is on 400km orbit

E = 1,500,000cd/(400km)^2 =9.48 * 10^-6

Luminance can be converted into magnitude of star by this formula

$$m = -\frac{\log\left(\frac{E}{2.5\times10^{-6}}\right)}{\log\sqrt[5]{100}} = -\frac{\log\left(\frac{9.48\times10^{-6}}{2.5\times10^{-6}}\right)}{\log\sqrt[5]{100}} \fallingdotseq \mathbf{-1.45}$$

Sirius, the brightest star in the Earth's night sky, has magnitude of **-1.46**

Our satellite can be bright as same as Sirius

Conclusion

- Our project purpose is studying construction of space infrastructure & doing technical demonstration of constructing large architecture toward SPS
- We aim to carry out demonstration to connect with 2020 Tokyo Olympic
- We are considering 3 types of demonstration model made by modular structure & solar array membrane
- Regarding ring shape demo model as tentative plan, We examine our demonstration
- Our demonstration satellite has LED and we observe it from ground
  It is imitation of SPS's power transmission system
- Our satellite will can be seen 2.6 times larger than Venus & bright as Sirius

End

Thank you for your attentions