

**Title:** The Service for Individual to Meet Space; Future Space Funeral

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**Need**

There are 6 billion people in the world and it will exceed 10 billion in the near future. Life is really good and filled with happiness, but unfortunately, no one can live forever. In the time of death, braved family or surviving people make grave to commemorate the dead at almost every culture. However, nowadays, some problems for a funeral ceremony are happening all over the world.

A dead should be laid to rest by one's or family's way based on religion and culture. However, it is impossible to make fine grave for all human kind because there isn't enough space on the Earth, especially in a country which has small land or in a culture which use large space to make the grave like Burial. If these situations about the grave continue, an amount of people who has problems for a funeral ceremony would increase and the time that we face social problems related it is not too far away. For instance, some people who traditionally bury the body will have to cremate because of lack of space, or to make matters worse, some people will not be able to make a grave for the same reason.

Thus, we suggest the space satellite mission to solve the problems above. The mission is "Space funeral and space grave which can visit after launch by using space satellite". People who belong to many cultures think that the God or a dead is in the sky generally. For example, we say "When people die, they are going to be a star in the sky" in Japan and Christian believe that "The heaven exists in the sky". We think that these images help to soften a sense of resistance to cremation and these are main reason we would like to suggest our mission as a solution of funeral problems.

In many cases, cemeteries or graveyards are located in outer city which has good access from a city. However, these locations are also good for industries, farming, and economic development. Hence the space funeral service has a lot of social benefits as well as personal because this service can compress area for cemeteries or graveyards.

A service for the space funeral is already exists. This service provided by Celestis, inc.<sup>1)</sup> is launch capsules which include cremated remains by rocket (Fig. 1 and Table 1). However, it is just only launch service and families can't see or visit cremated remains in orbit. All ceremonies are taken on the ground, so it is hard to feel the journey of departed soul to space for families. Thus, in our mission, we launch a grave satellite which includes many cremated remains for funeral and main satellite "Grave" is accompanied co-satellite "Visitor" to see a grave satellite in orbit. This system enables users to visit the grave after launch. In addition, the satellites used in this mission are planned to reentry to the atmosphere in final sequence of the mission with all components and never left space debris in orbit all mission sequences.

**Mission Objectives**

1. To offer a new space funeral service by which user can visit their grave in orbit
2. To create a new space related culture for personal use.
3. To achieve nano-satellite deorbit maneuver.
4. To demonstrate appearance check technologies in orbit for satellite.

**Concept of Operations**

Key mission elements and a system of funeral service in space are shown in Fig. 2. There are two points of focus for this service. The first point is that *User* receives the Sat("Grave") 's images taken by the Sat("Visitor"). The second point is that *User* receives the movie of the *Grave's* reentry. In addition, there is one sub-service. After the *Grave's* re-entry, the *Visitor* remains in orbit. So, earth images taken by the *Visitor* are sold to *Public*.



Fig. 1 Existing service image provided by Celestis, inc. and capsul picture used in the service which include cremated remains

Table 1 Result of Existing service (Celestis, inc. launches data)

No.	Launch	User	Rocket	Service
1	1997	24	Pegasus	Earth Orbit
2	1998	-	Athena	Luna
3	1998	30	Taurus	Earth Orbit
4	1999	36	Taurus	Earth Orbit
5	2001	50	Taurus	Earth Orbit
6	2007	-	SpaceLoft XL	Earth Rise
7	2008	-	Falcon 1	Earth Orbit
8	2009	-	SpaceLoft XL	Earth Rise
9	2010	-	SpaceLoft XL	Earth Rise

## Satellite System Design Club

An operation plan of this service is shown in Fig. 3. This service is started at 1.5 month after launch. Considering debris, the *Grave* reentry as *shooting star service*. In later phase, only the *Visitor* keeps taking images of the earth. Total operation term is about 3 years.

In operation, we use one ground station. We operate two satellites by time-division system because satellites spread after orbital change for re-entry. In addition, we use TLE supplied by NORAD and do not make ranging facility. Thus, we provide this service at lower price.

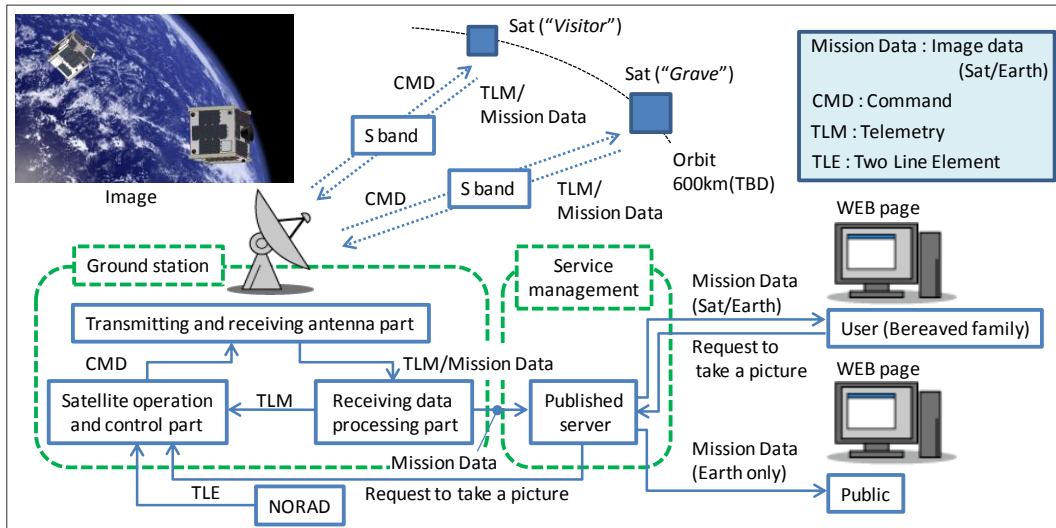


Fig. 2 System of funeral service in space

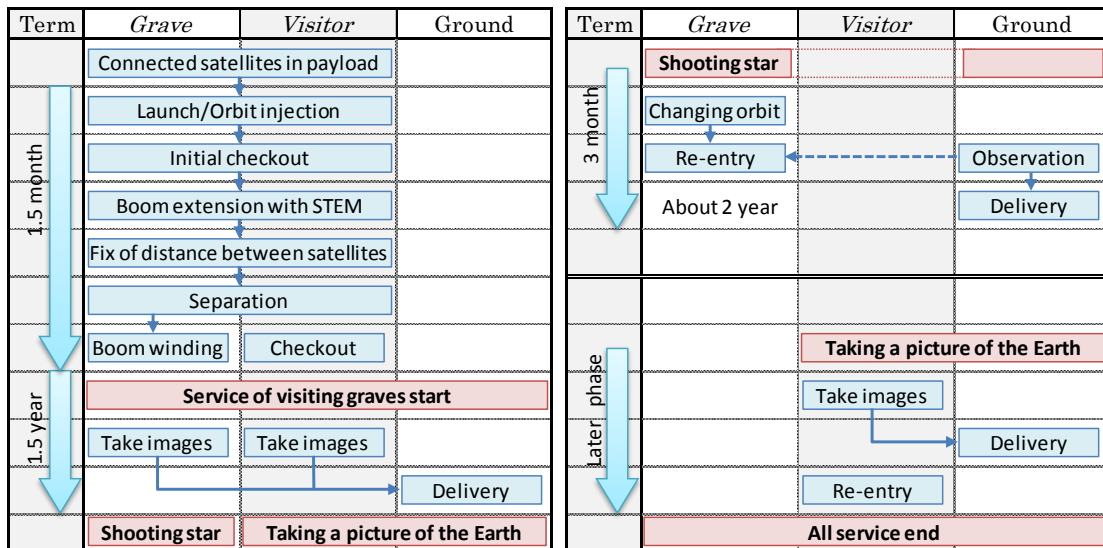


Fig. 3 Operation plan

## Key Performance Parameters

Table 2 Key Performance Parameter

Parameter	Subject	Value	Complement
<b>For service of visiting graves</b>			
Length of boom extension	Grave	5m	To prevent two satellites from colliding with each other
Resolution of imager	Visitor	$\leq 0.5$ mm	To discriminate a character written at surface of <i>Grave</i> and to confirm that there are the deceased's grave in space
Rotation rate (each axis)	Visitor	$\leq 0.3$ rad/s	To take a image without blurring
<b>For service of shooting star</b>			
Necessary $\Delta V$	Grave	$\geq 115$ m/s	To change an altitude of perigee from 600km to 200km for a re-entry
Accuracy of attitude determination	Grave	$\leq 15$ deg	To thrust gas in an effective direction (If satellite's $\Delta V$ is 120 m/s, a minimum effective $\Delta V$ satisfy a necessary $\Delta V$ because $120 \times \cos 15^\circ \approx 115.8 > 115\text{m/s}$ )

**Space Segment Description**

Space segments (Fig. 4) consist of the *Grave* which has cemeteries and the *Visitor* which takes images of the *Grave*. Main design parameters of each satellite such as size, weight, power, battery, and transmission power are shown in Table 3.

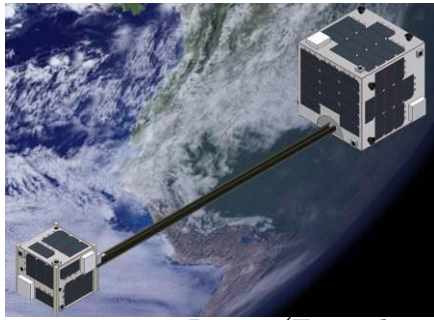


Fig. 4 Space segments Image (Extending STEM)

Table 3 Main design parameters

	<i>Grave</i>	<i>Visitor</i>
Size	250×250×250mm	150×150×150mm
Weight	15kg	5kg
Power supply	22W	15W
Battery	20W	13W
Tx Power	2W	
Bitrate	512kbps-1Mbps	

The sequence of the space segments from a rocket separation to an ordinary operation is described below. First, both satellites are mechanically connected with in the rocket separation phase. Second, the *Grave* extends STEM (Storable Tubular Extendible Member)<sup>2)</sup> with a length of 5 m after finishing attitude stabilization and a primary system checkout. Finally, the *Visitor* is separated from the *Grave* with satisfying the CW (Clohessy-Wiltshire) solution<sup>3)</sup> orbit. After that, each satellite starts an ordinary operation. Next, details of each satellite are described.

First, a system block diagram and onboard hardware lists of the *Grave* are respectively shown in Fig. 5-6 and Table 4. RCS and OME are loaded as AOCS (Attitude and Orbit Control System). Because the *Grave* has S-band broad-directional antenna, the attitude control is only needed in the following mission phases: attitude stabilization after rocket separation, attitude stabilization after the *Visitor* separation, and attitude control in orbital maneuver. The solid-fueled thruster which was used in DASH mission<sup>4)</sup> is adopted as the OME, and eight small lightweight cold-gas thrusters are adopted as the RCS. With using these components, it is possible to achieve an amazing lightweight less than 4 kg with all thrusters, fuel and tanks. Therefore, the feasibility in weight of the AOCS using thrusters is guaranteed in spite of a nano-satellite (less than 15 kg). In addition, the OME realizes 120 m/s delta-V. Thus the orbital transfer from the circular orbit with an altitude of 600 km results in an elliptical orbit whose altitude of perigee is 200 km and altitude of apogee is 600 km. In this orbital transfer, the orbital lifetime of the *Grave* becomes less than several months. Therefore, it is confirmed that the ‘*Shooting Star service*’ is possible. STEM is adopted as a deploying system in the *Grave*. STEM which is made of thin CFRP (carbon fiber reinforce plastic) is a plate-spring material

Table 4 Onboard hardware list: *Grave*

Subsystem	Component		Amount
	Full name	Abbr.	
EPS	Solar Cell	SC	108
	Battery	Bat	8
	Heater	HEAT	1
TRx	S-Band Antenna	S-ANT	2
	Transponder	TRP	1
AOCS	Tank (Solid)	TANK-S	1
	Orbital Manuvering Engine	OME	1
	Coarse Sun Sensor	CSS	6
	GPS Antenna	GPSA	2
	GPS Receiver	GPSR	1
	Gyroscope	GYR	1
	Reaction Control Subsystem	RCS	8
	Tank (Gas)	TANK-G	1
	Sensor	Temperature Sensor	TSN
DEV	Deploying	DEP	1
	Separation	SEP	2
C&DH	On Board Computer	OBC	1
Mission	Camera	CAM	1
	Cemetery	CEM	200

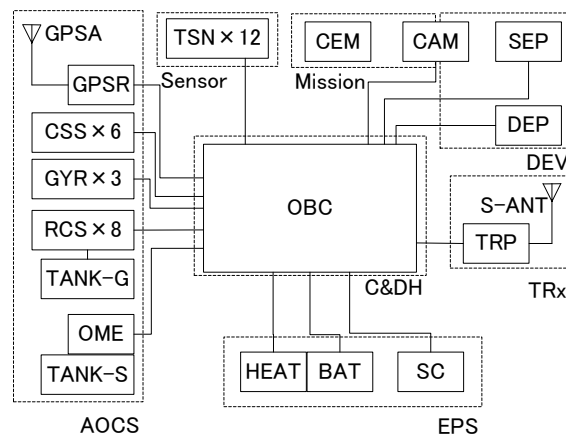


Fig. 5 System block diagram: *Grave*

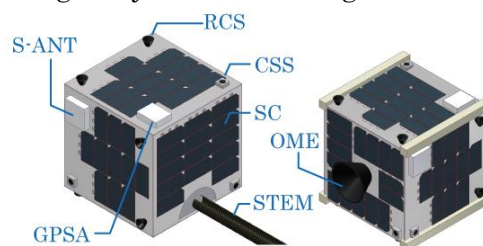


Fig. 6 Appearance of *Grave*

which is used as a deploying system in antenna and solar array panel. Moreover, EJECTOR<sup>5)</sup> is adopted as a separation system which is a simple structure and a reusable system. Basically, the *Visitor* takes images of the cemetery in the *Grave*. In addition to this, a mission camera to take images of owns cemetery is located on the end of STEM as a countermeasure against the emergency of the *Visitor*.

Second, a system block diagram and onboard hardware lists of the *Visitor* are respectively shown in Fig. 7-8 and Table 5. A key demand for the *Visitor* is an assured taking images of the *Grave*. Generally, there are two famous solutions to achieve this demand: accurate attitude control or increasing the number of cameras. In a small satellite, it is extremely difficult to control attitude accurately to keep the target in the visual field of mission camera. Thus, in this mission, six cameras are respectively located in each panel. Using CSS for judgment of taking images by camera, the *Visitor* prevents its cameras from being deteriorated by taking image of the sun. In addition, OBC deletes pitch-dark pictures with simple algorithms in order to reduce downlink data.

Table 5 Onboard hardware list: *Visitor*

Subsystem	Component		Amount
	Full name	Abbr.	
EPS	Solar Cell	SC	72
	Battery	Bat	5
	Heater	HEAT	1
TRx	S-Band Antenna	S-ANT	2
	Transponder	TRP	1
ADS	Coarse Sun Sensor	CSS	6
	GPS Antenna	GPSA	2
	GPS Receiver	GPSR	1
Sensor	Temperature Sensor	TSN	10
C&DH	On Board Computer	OBC	1
Mission	Camera	CAM	6

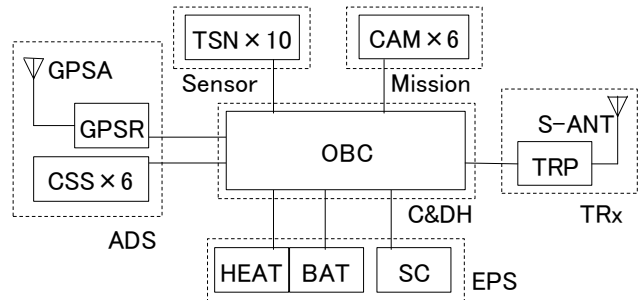


Fig. 7 System block diagram: *Visitor*

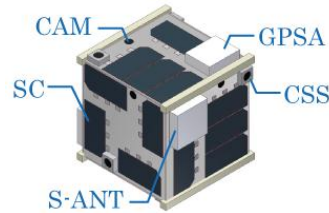


Fig. 8 Appearance of *Visitor*

**Orbit/Constellation Description**

The CW solution is used for the orbital maintenance for the *Visitor* to take images of the *Grave* from various angles. Separation sequence of the *Visitor* is shown in Fig. 9. The *Visitor* separates vertically in a standard orbital plane by a position 5m away from the *Grave* with the deployment mechanism, and moves on the oval in surroundings of the *Grave* and always observes it with the cameras. The details of the orbit refer to the reference.

The relation between the *Grave* and the *Visitor* can be calculated by the solution of the CW solution shown in Fig.10. In the case of  $x_0=5[m]$ , a necessary initial speed in the separation is to be  $dy_0=-0.01238[m/s]$ , and the *Visitor* comes to move drawing the elliptical orbit, which is major axis 10m and minor axis 5m, while moving in a standard orbital plane as shown in Fig.9-④.

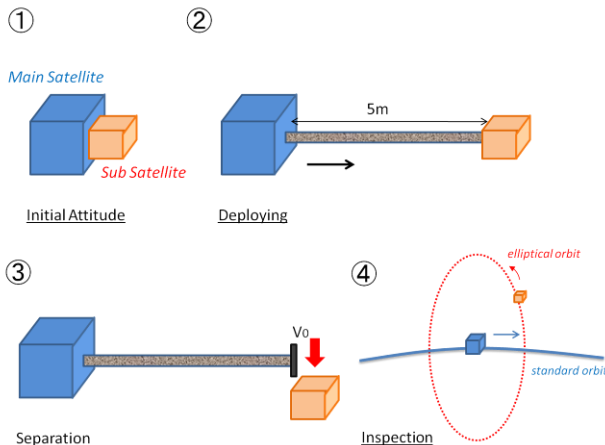


Fig. 9 Separation sequence of the *Visitor*

**Definition**

$$C = \sqrt{\left(3x_0 + \frac{2\dot{y}_0}{n}\right)^2 + \left(\frac{\dot{x}_0}{n}\right)^2} \quad \sin \psi_0 = -\left(3x_0 + \frac{2\dot{y}_0}{n}\right) / C \quad \cos \psi_0 = \frac{\dot{x}_0}{n} / C$$

$$D = \sqrt{\left(\frac{\dot{z}_0}{n}\right)^2 + z_0^2} \quad \sin \phi_0 = -\frac{\dot{z}_0}{n} / D \quad \cos \phi_0 = \frac{z_0}{D}$$

**Clohessy-Wiltshire equations**

$$x = x_c + C \sin(nt + \psi_0)$$

$$y = y_{c0} + \dot{y}_c t + 2C \cos(nt + \psi_0) = y_c(t) + 2C \cos(nt + \psi_0)$$

$$z = D \cos(nt + \phi_0)$$

where

$$y_{c0} = y_0 - \frac{2\dot{x}_0}{n} \quad \dot{y}_c = -6nx_0 - 3\dot{y}_0 \quad y_c(t) = y_{c0} + \dot{y}_c t \quad x_c = -\frac{2\dot{y}_c}{3n}$$

Fig. 10 Clohessy-Wiltshire equations and solution



**Implementation Plan**

Project cost and schedule are shown in Table 6 and Fig.11. It assumes that the *Space Funeral* will be regularly done in the future, and development the ground station equipment cost could be reduced after the second satellite by Initial investment. Therefore, the following risks are given to make space funeral by nano-satellites industrialize. In the point of demand for the mission, there is enough demand in the light of the existing space funeral by the rocket, so we are convinced that demand can be improved further by clearing problem of the price

Table 6 Project Cost

Item	Costs[yen]	Remarks
Development	50,000,000	Deployment System Separation System
Manufacture	100,000,000	BBM/PFM(EM)
Environment Test	50,000,000	Thermal Vacuum/EMC Vibration/Shock
Launch	50,000,000	Piggy Back
Ground Station	100,000,000	Opened New GS
Operation	100,000,000	2 year operation
Total	450,000,000	

■ Project Risk

1. New development elements of Deployment System and Separation System
2. Satellite surveillance technology by the *Visitor*, such as orbit maintenance and taking images
3. Transition to reentry trajectory
4. Operation period due to mission demand, i.e. how many years do customers need as a *space funeral?*
5. The cultural barrier of the funeral tradition

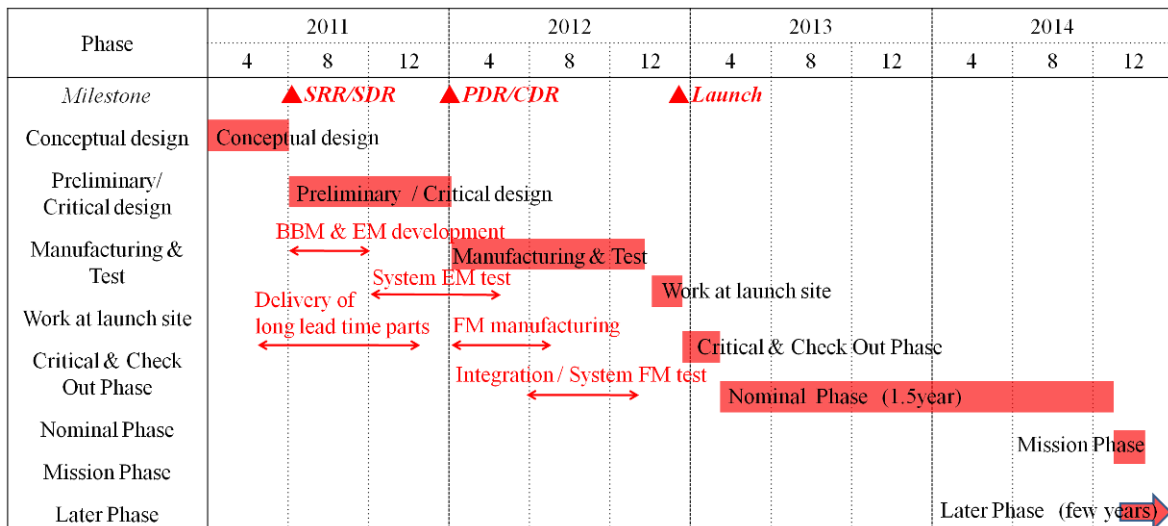


Fig.11 Project schedule

**References**

- 1) Celestis, inc.(<http://www.celestis.com/default.asp>)
- 2) Taihei Ueno, Mitsushige Oda," *Development of Extendable Robotic Arm For Astronaut Support Robot*", 59<sup>th</sup> International Astronautica Congress, 2008, IAC-08-C2.2.8
- 3) W.H.Clohesy and R.S.Wiltshire. " *Terminal Guidance System for Satellite. Rendezvous*", Journal of Aerospace Science, 1960, Vol.27, Sept., pp.653–658.
- 4) T. Abe, Y. Morita, J. Kawaguchi, Y. Inatani, " *Development status of the high-speed reentry system---DASH*", 2nd International Symposium Atmospheric Reentry Vehicles and Systems, at Arcachon, France, (2000).
- 5) TiNi AEROSPACE, Inc. (<http://www.tiniaerospace.com/erm/ejector.html>)