# SPACE CAPSULE USING ENERGY OF GRAVITATIONAL FIELD FOR FLIGHT CONTROL

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## ABSTRACT

This paper presents a space capsule which uses energy of gravitational field of Earth for flight control. This capsule can be used for current transportation between Earth and International Space Station (ISS) or the future space hotels. The Space Shuttle was considered for three decades the best solution for transportation of materials and crews to Earth's orbits and back. However, reality has shown that the space shuttles are extremely expensive vehicles both to be built and maintained than the classic rockets and space capsules. In addition, the reliability of space shuttle as transportation mean was proved to be inferior to the reliability of classic rocket + space capsule. These facts brought revived the classic rocket and capsule. Specialists estimate today that over the next 50-100 years, rockets and space capsules will be the main transportation means to space and back to Earth. On the other hand, it is estimated that transportation needs between Earth surface and Earth orbit will increase due to increasing of frequency of transports to the International Space Station and developing of the new commercial branch of space tourism. At present there are already announcements that national and private space stations and space hotels will be built in the next years on Earth orbit. The increased traffic between orbit and the Earth's surface will raise difficult problems related to cost and safety. According to current procedures, a large control team of scientists, which is based on the ground, assists the re-entry of each capsule. It will be really very costly to maintain these procedures when tens of capsules need to re-enter day and night. According to expectations, the transport capacity of a capsule will increase to 5-7 places maybe even more and crews are expected to become more involved role in flight maneuvers. The new space capsules should be much improved in order to accomplish these new transportation requirements. The space capsule presented in this paper is advanced space equipment able to satisfy future challenges generated by increased space traffic. The new capsule is braking in atmosphere as the classic one using ablative layers and parachutes. In addition, the new capsule is equipped with two deployable plates, which are symmetric, self-rotating plates and can be used to provide additional lift and maneuvering thrust. The plates are telescopically folded inside the space capsule. These plates can rotate independently in bearings affixed to the capsule structure. After the capsule speed is reduced by parachute, the plates are progressively extended. Due to Mouillard's effect, the plates begin to rotate and generate an aerodynamic force perpendicular to the direction of capsule velocity. This force is decomposed in a vertical force (lift force) and a tangential force which is a traction force as in the case of a glider. These forces are used both for reducing the vertical for maneuvering. Maneuvers can be easily performed. As assume for example, that the length of the left side plate is reduced compared to that of the right side plate. Experiments performed with low scale models show the capsule turns to the left. Alternately, both plates might have symmetric holes. Except for maneuvers, the holes are closed by sliding covers. If the hole in the right side plate is opened while the hole in the left side plate is closed, experiments with rotating plates show that capsule should turn to the right. The vertical speed can be controlled by changing the length of plates. When the length increases, the lift force increases and vertical speed is reduced and vice-versa. Such a capsule can even land on a regular tarmac because the vertical speed and flight direction can be controlled using the rotating plates. Another important advantage of this new type of capsule is that the two plates constitute a backup parachute. A disaster occurs, if the main parachute(s) of a current capsule fail to open or the drogue engines do not work properly. If, the main parachute(s) of the new type of capsule presented here fails to open to open or the drogue engines do not work properly, the plates are deployed and progressively extended. Both plates will auto rotate. The capsule will fly like a glider, as Space Shuttle did and would land on a normal runway. In this case, although the braking force created by the rotating plates is smaller than the braking force created by a parachute, the trajectory is much lengthened and the braking period increases.
Keywords: space capsule, Mouillard effect, space tourism

## NOMENCLATURE

$C_z$, lift coefficient, dimensionless
F, aerodynamic force, [N]
W, weight, [N]
u, peripheral speed, [m/s]
V, air speed, [m/s]
ω, angular speed, [$s^{-1}$]
Γ, circulation, [$m^2/s$]
ρ, air density, $kg/m^3$

## I. INTRODUCTION

### I.1 The Need for Space Capsules

The need for space capsules increased recently due to growing amount of gods and increased number of crews required to services the International Space Station, the retirement of the Space Shuttle and increased demand for space tourism.

NASA announced that Space Shuttles will no longer be used to transport people and goods to space and back. The reasons are economical: in 30 years the Space Shuttle achieved over 135 missions and suffered two disasters (Challenger in 1986 and Columbia in 2003). The cost of each Space Shuttle mission was enormous. Enormous was the cost of maintenance, too. Finally these causes led to the closure of this space program.

According to estimates, during the next 50-100 years rockets and space capsules will have a leading role in space operations. NASA pays now billions of USD to private companies for manufacturing commercial space rockets capable of carrying astronauts to the International Space Station and back.
In 2016 Russians intend to place on orbit a space hotel (fig.1). It seems that the number of such hotels will increase rapidly. Implicitly, space traffic and the need for capsules will greatly increase [1].


Figure 1-Rusian space hotel

Such high intensity traffic will raise some difficult technical and financial problems. We have to remember that the re-entry of a single Apollo capsule required the services of a NASA control station operated by hundreds of scientists plus hundreds of other personnel involved in the recovery of the landed capsule.

In addition, the history of space capsule accidents shows that this transportation mean still needs reliability improvements.

### I.2 The State of the Art

The state of the art is represented by the experimental capsule Dragon V2 (fig.2) [2], which is powered by SuperDraco engines (fig.3).

Figure 2-Dragon V2

Figure 3-SuperDraco engines

The eight SuperDraco engines [3] powering this capsule also have the role of saving the astronauts in case of a launch failure and of allowing powered-landings on Earth (fig.4) [4], thereby assuring an important safety progress.

Figure 4-Dragon V2 landing

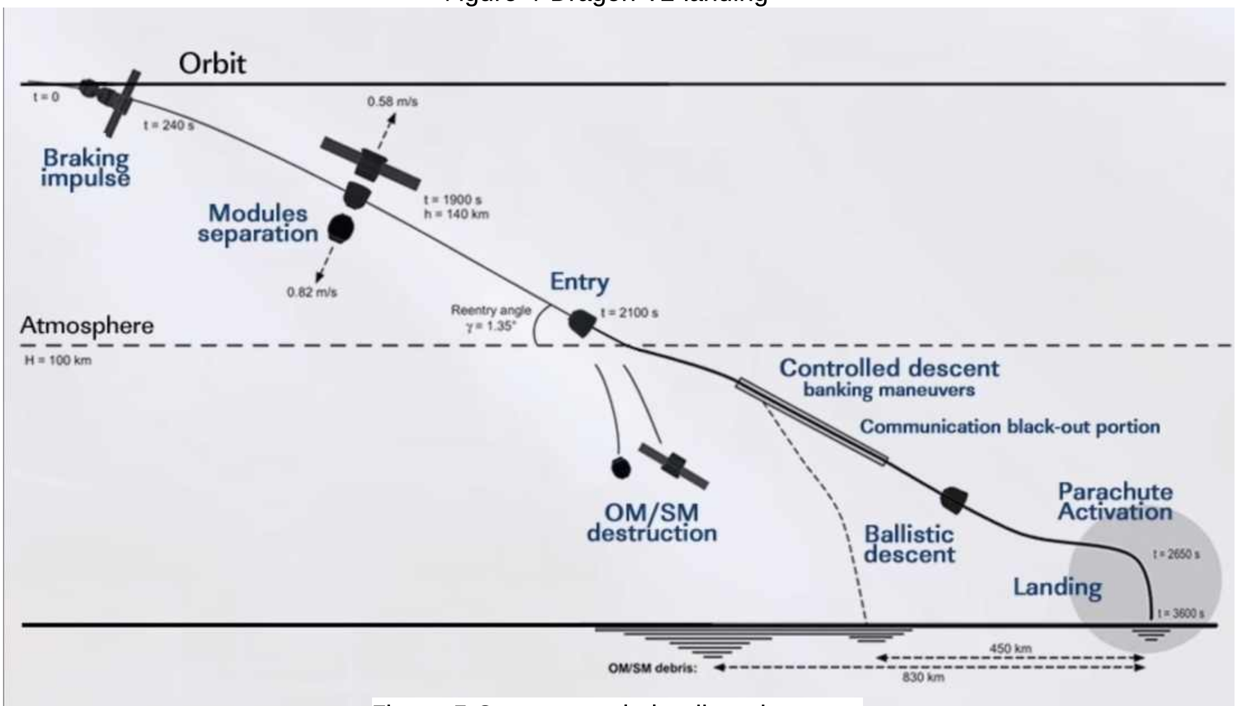


Figure 5-Soyuz capsule landing phases

The landing phases of a classic capsule, such as Soyuz are presented in fig. 5 [5].

Fig.6 shows the Space Shuttle's landing pattern called 'Heading Alignment Circle' (HAC) [6]. It is easy to see that the Space Shuttle is more maneuverable than any type of capsule inclusive the advanced Dragon V2. This is possible because the Space Shuttle can glide using its energy in the gravitational field of Earth while current capsules can not.

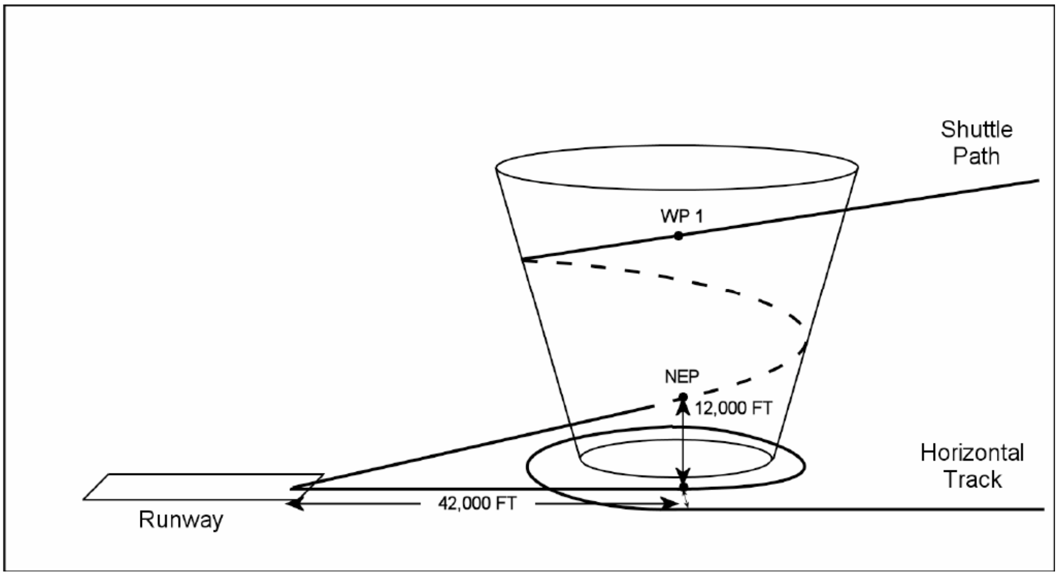


Figure 6-Landing phases of Space Shuttle

## II. PRESENTATION OF CONCEPT

The new type of capsule has two flat plates folded inside the capsule body as presented in fig.7. Every plate has a spindle which can rotate freely inside two bearings fixed in a housing. The housings can be rotated in the vertical plane untill their axes are positioned horizontally as shown in fig.8.

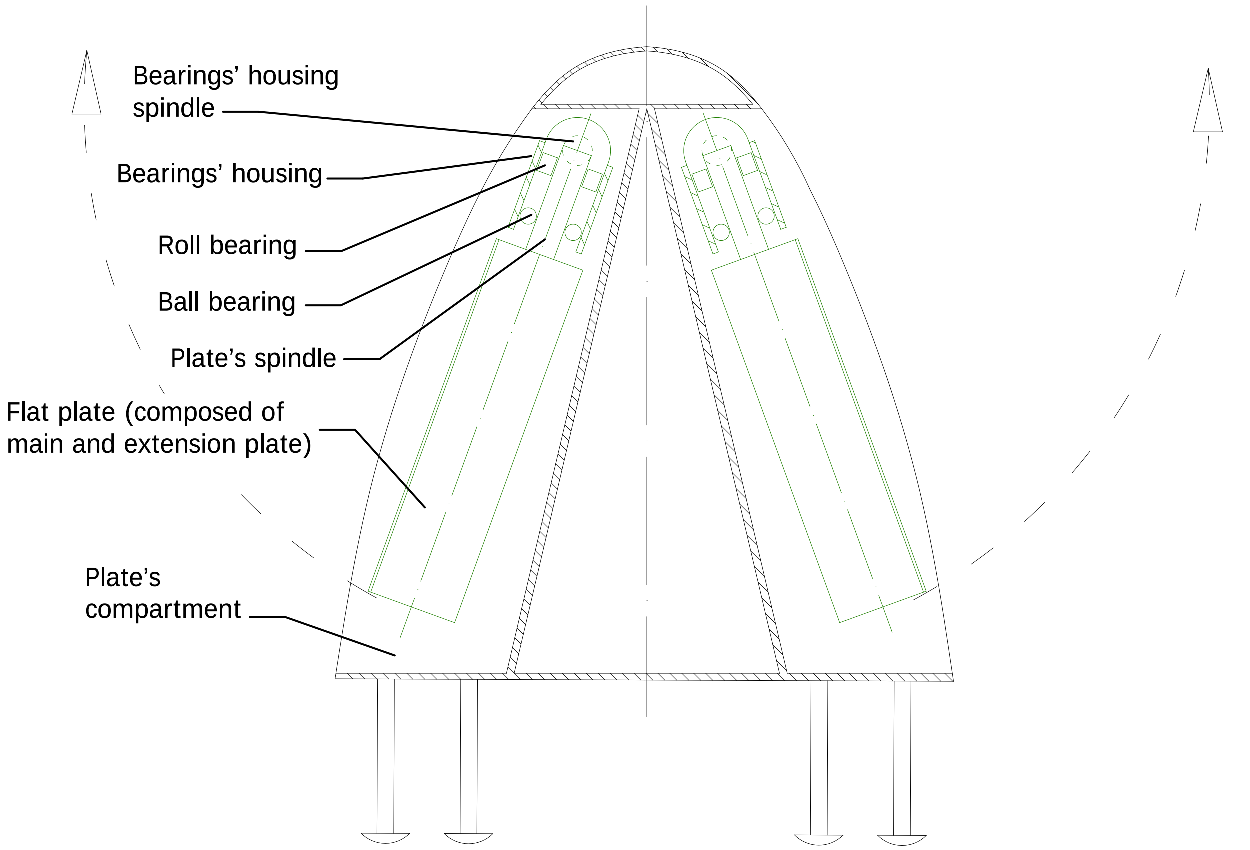


Figure 7-New type of capsule having two rotating plates folded inside

In air stream, such plates will auto rotate. The auto rotation of a plate in the presence of air stream having speed, $V_0$ ( speed of capsule in atmosphere) generates an aerodynamic force which is proportional to the product of the vortex intensity and speed of the capsule.

The lift generated by a plate falling in autorotation was discovered and studied by Mouillard. For a plate rotating around its longitudinal axis (fig.9), the circulation Γ, must have the value [7]:

$$\Gamma = \frac{\pi\omega c^2}{4} \tag{1}$$

where ω is the rotation speed of plate and c is the plate width (chord).

When the rotating plate is placed in air stream having speed $V_0$, (fig.10), the unitary aerodynamic resultant force F (force given by 1 m of plate length) is according to Kutta-Jukovski formula:

$$\vec{F} = -\rho\vec{\Gamma} x \vec{V}_0 \tag{2}$$

where ρ is air density.

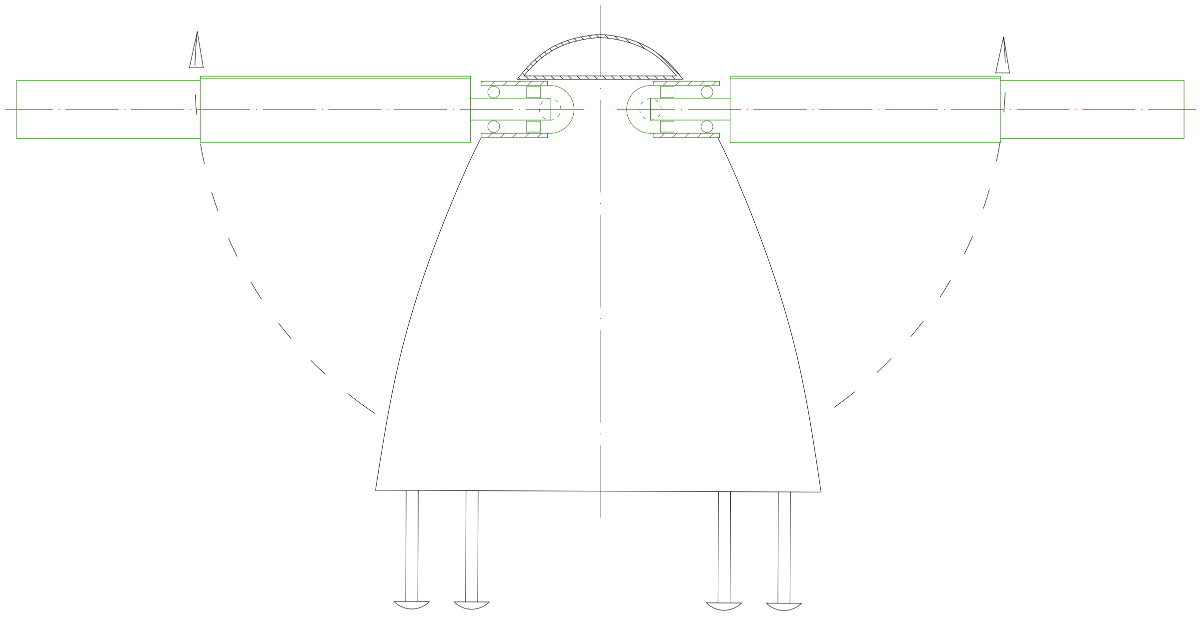

Figure 8-Deploying of rotating plates

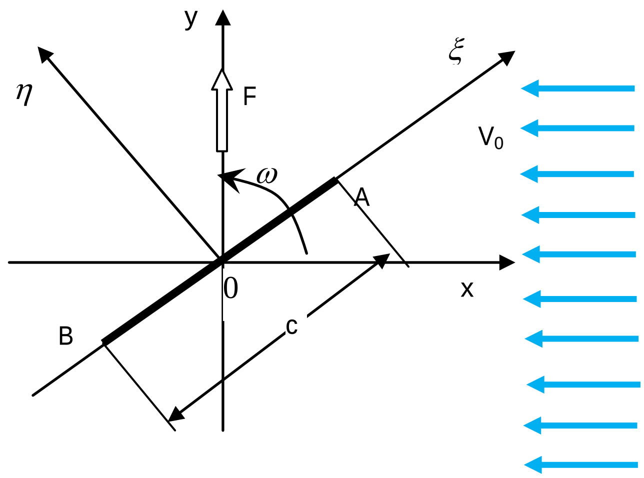


Figure 9-Lift created by a plate in rotation

When the angular speed, ω, is a constant, the speed $u_0$ of plate extremities A & B is given by:

$$u_0 = \omega \frac{c}{2} \tag{3}$$

and the unitary lift coefficient is given by:

$$C_z = \frac{F}{\frac{\rho}{2} c V_0^2} = \frac{\rho \frac{\pi}{4} \omega c^2 V_0}{\frac{\rho}{2} c V_0^2} = \pi \frac{u_0}{V_0} \tag{4}$$

The real value of $C_z$ is a smaller than the value given by (4) :

$$C_z = k \frac{u_0}{V_0} \tag{5}$$

where $k < \pi$.

If the plate length is L (the equivalent of plane wing span), then the total aerodynamic resultant force created by rotating plate is:

$$F_t = C_z \frac{\rho}{2} c V_0^2 L = k \frac{u_0}{V_0} \frac{\rho}{2} c V_0^2 L \tag{6}$$

In the case of a space capsule which flies using Mouillard's effect, the total aerodynamic force of the two identical plates $F_t$* is:

$$F_t^* = 2F_t = 2C_z \frac{\rho}{2} c V_0^2 L = 2k \frac{u_0}{V_0} \frac{\rho}{2} c V_0^2 L \tag{7}$$

It is easy to see that rotating plate has important advantages relatively to a fixed plate. Due to the Z shape of plate, peripheral speed $u_0 \rightarrow V_0$ and $C_z \rightarrow k \sim \pi$. For this reason the rotating plate produces a higher lift than a fixed plate (wing).

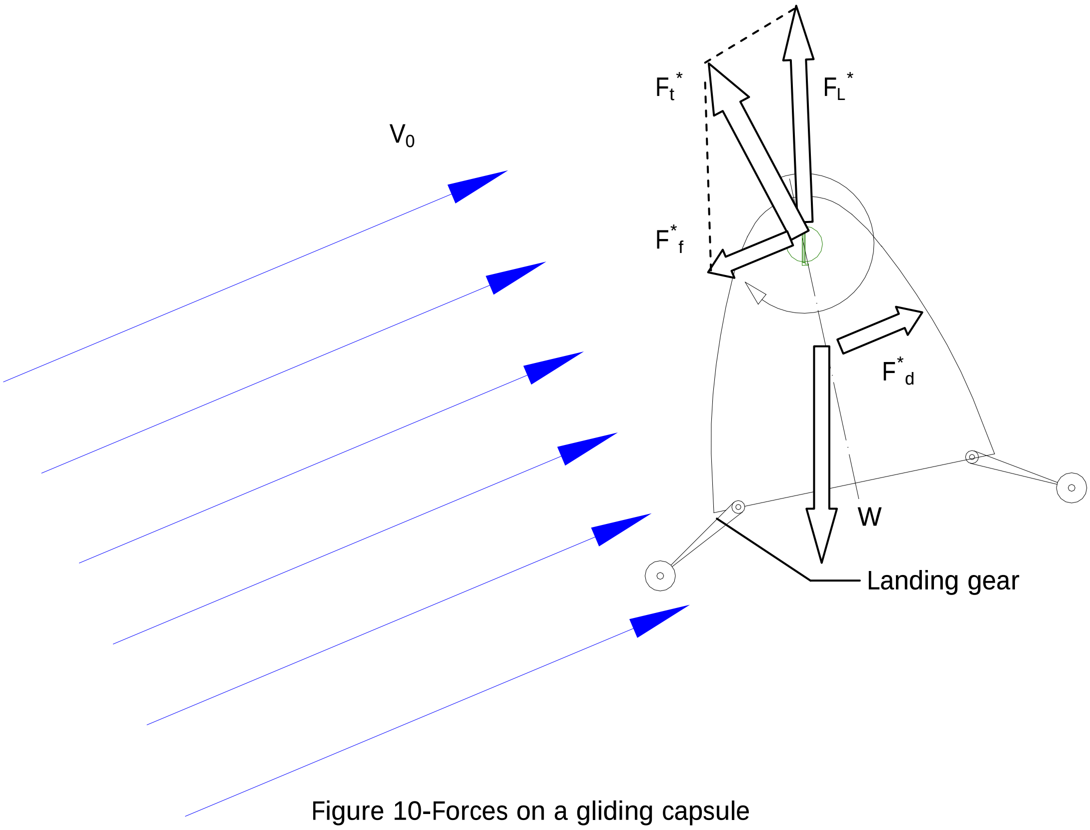


Figure 10-Forces on a gliding capsule

In fig. 10 one can see that such a space capsule will have a gliding trajectory. The aerodynamic force $F^*_t$ can be decomposed in two forces: Lift force $F^*_L$ which balances the capsule weight, W, and traction force $F^*_f$ which compensates the dynamic drag $F^*_d$ pulling the capsule forward on a gliding trajectory.

Formulas (5) & (6) show that such a capsule can be maneuvered even more easily than a glider: if the rotation speed ω of one plate is reduced (for example using a fiction or magnetic force applied on plate's spindle), $u_0$ decreases, $C_z$ decreases, the aerodynamic force $F_t$ decreases and the capsule turns to the side of the slowed plate.

If the total length L of plate decreases on a side (i.e. the plate extension plate is retracted), the aerodynamic force $F_t$ will decrease and the capsule will turn toward the side of the retracted plate. A very simple method is to drill symmetric holes in the both plates. Both holes are normally covered by adequate sliding covers. If the cover of one hole is retracted, $F_t$ decreases and the capsule will turn to that side.

The mentioned technologies can be easily designed and for this reason we do not present more details in this paper.

It is important to note that when perturbation is maintained a long time, the trajectory of a capsule will be a helix. If the perturbation is cancelled, the capsule's trajectory will straighten again. For this reason the Mouillard type capsule can have the Space Shuttle's landing pattern called 'Heading Alignment Circle' (HAC).

## III. MATERIALS AND TECHNOLOGY

The plates are deployed after the capsule speed is reduced by dynamic drag of shield and drogue parachutes (subsonic speed ~ 200 km/h).

The space capsule body will be built using current technology. Rotating plates which must be light and strong should be manufactured from titanium alloys. The main plate section should be Z shaped for increasing peripheral rotation speed, $u_0$, which leads to increased lift coefficient $C_z$.

On the other hand, the Z shape increases plate's strength and controls the flight direction of capsule (fig.11).

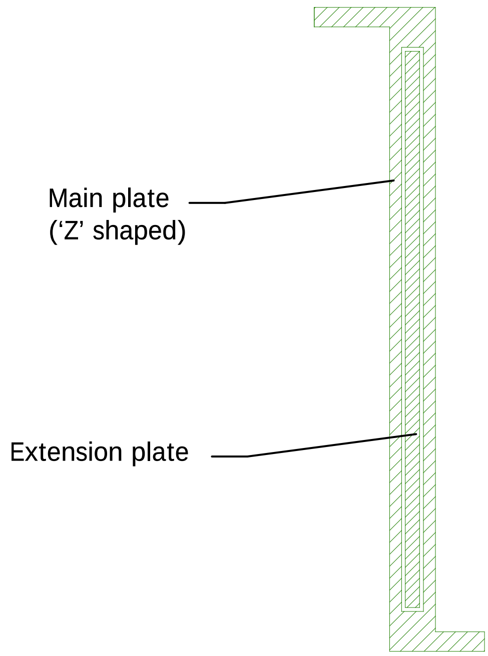


Figure 11-Section through rotating plates showing 'Z' shape of main plate

## IV. CONCLUSIONS

The traffic of materials and crews between Earth surface and orbit (ISS and space hotels) will dramatically increase in the next years.

This paper presents an advanced type of space capsule for space tourism and transport to and from International Space Station (ISS) or space hotels.

Unlike present capsules, the new capsule has two foldable rotating plates. When these plates are deployed, they begin to auto rotate and as a consequence aerodynamic forces appear on both plates allowing the space capsule to fly as a glider. Maneuvering of Mouillard capsule is simpler than maneuvering a normal glider.

The plates can be used for capsule maneuvers during the last part of a reentry or as an ultimate rescue mean if landing engines or main parachute do not work.

Such a capsule should be safer than the classic capsule or the Space Shuttle.

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