# Sp512 Conception de Lanceurs
# Project : Launcher conception

## 1 Context

You are part of IPSA Rocket Company (IRC) working on the launcher conception departement involved in the development of launcher for space agencies. Your work is to design a launcher for one of specific missions described in Sect. 3. The design consists in determining the optimal staging of the launcher to make the mission a success :

- the number of staging ;
- the appropriate propellant type ;
- the distribution of masses in each stage ;
- the azimut.

## 2 Propellant and Staging

IRC has developed several type of stages depending on the propellant. The characteristics are described in Table 1.

**Table 1** – Characteristics of stages/propellant of ILC

| Name | Code | possible stages | Isp (vaccum) s | Mean Isp s | structural index |
|---|---|---|---|---|---|
| Refined Petroleum 1 | LOX-RP1 | 1,2,3 | 330 | 287 | 0.15 |
| Liquid oxygen - liquid hydrogen | LOX-LK2 | 2,3 | 440 | - | 0.22 |
| Solid-Liquid | Solid | 1 | 300 | 260 | 0.10 |

Solid propellant can only be used in first stage, whereas LOX-LK2 is only usable for a second or third stage. Stage specifications are given in Table 2. Security departement does not allowed a total mass bigger than 1500 tons.

**Table 2** – Stages specifications

| | minimum structural mass kg | maximum structural mass kg |
|---|---|---|
| Stage 1 | 500 | 100 000 |
| Stage 2 | 200 | 80 000 |
| Stage 3 | 200 | 50 000 |

To respect equilibrium of the launcher, the total mass of stage 1 should be bigger than the mass of the rest of the launcher (stage 2 + stage 3 + payload), and the total mass of stage 2 should be bigger than the mass of the rest of the launcher (stage 3 + payload). The fairing mass is neglected in the study.

# 3 Missions

1. **Cargo to ISS** : Roscosmos requires a cargo to ISS
2. **Military satellite** : Military agency requires a secret satellite on a polar circular orbit
3. **GEO satellite** : ESA requires a GEO satellite. Payload includes the engine and propellant to injection on GEO (*i.e.* to change inclination and make the orbit circular at apogee)
4. **SSO satellite** : NASA requires a Sunsynchronous (SSO) satellite at constant altitude $z = 567$ km

The specifications for each mission are given on Table 3. An error of 1 km and 0.1 deg compared to required orbit is allowed.

**Table 3** – Mission specification

| | **Mission 1** | **Mission 2** | **Mission 3** | **Mission 4** |
|---|---|---|---|---|
| **Client** | Roscosmos | Military | ESA | NASA |
| **Injection/Perigee altitude** (km) | 410 | 340 | 200 | 567 |
| **Apogee altitude** (km) | 410 | 340 | 35786 | 567 |
| **Orbit inclination** (deg) | 51.6 | 90 | 5.2 | 97.6 |
| **Mass of the payload** (kg) | 32000 | 290 | 3800 | 1150 |
| **Launchpad** | Baikonur | Vandenberg | Kourou | Cap Canaveral |
| **Launchpad latitude** (deg) | 45.6 | 34.7 | 5.2 | 28.5 |
| **Difficulty** | ★★★★ | ★ | ★★★ | ★★ |

# 4 Losses

The losses department of IRC has study the losses for different combinations of stages and altitude injection. They finally found that the losses mainly depend on the altitude injection. Fig.1 shows the total losses in relation to the injection altitude. They found a relation giving the losses depending of altitude $z$ (in km) valid for the range $[200, 1000]$ :

$$\Delta V_{\text{losses}}(\text{in m/s}) = 2.452 \times 10^{-3} z^2 + 1.051 z + 1387.50$$

# 5 Objectives/Tasks

## 5.1 Objectives

Your main objective is to determine the optimal staging of a launcher for **one of the mission** detailed in Sect. 3 according to the specifications presented in Sect. 2. It consists in the determination of :

- the number of staging ;
- the appropriate propellant type ;
- the distribution of masses in each stage ;
- the azimut.

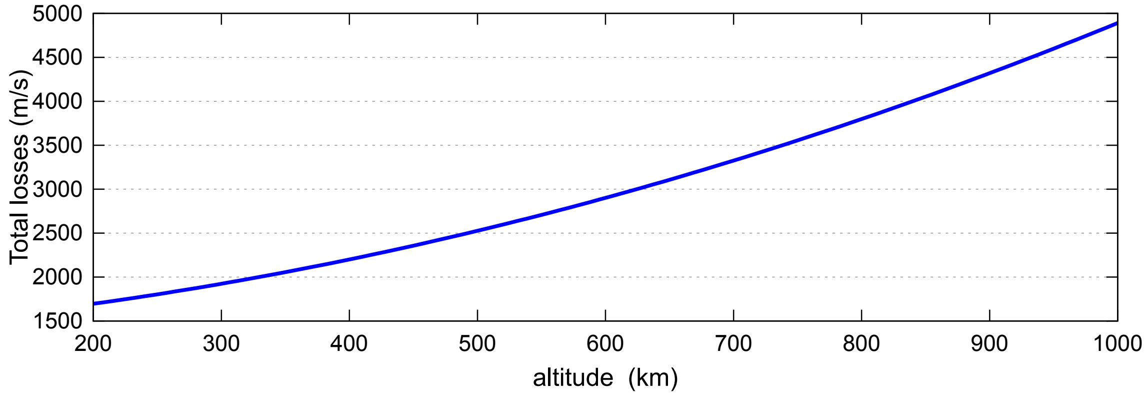


**Figure 1** – Total losses related to the altitude injection

### 5.2 Tasks

By group of 3 persons (see list of groups in Sect. 6), your task is to **write a technical report** in English, explaining the optimal staging. The report should explained and detailed :

1. Choice of the mission and injection requirement (velocity and altitude at injection, azimut of the launch)
2. Losses, initial velocity and $\Delta V$ requirement
3. Optimal staging (choice of propellant, number of stages and distribution of masses)
4. Expected orbit (check of expected orbital elements)

To check your result, the IRC numerical departement has developed a tool for that purpose : `http://josselin.desmars.free.fr/work/teaching/launcher/`

Send the report by email (`josselin.desmars@ipsa.fr`) before **8th December 2020, 18h TU**.

### Data

For calculation and documentation, the IRC had adopted the following value for the constantes :

— Earth gravitation at sea level : $g_0 = 9.80665$ m/s

— Earth radius : $R_E = 6378.137$ km

— Earth rotation rate : $\Omega_E = 6.300387486749$ rad/d

— Earth GM : $\mu = 3.986005 \times 10^5$ km$^3$/s$^2$

## 6 List of groups

Group 1. ZIND Thomas - SHARMA Abhijeet - NISTOR George-Constantin

Group 2. ROLIN Alexis - DE CLAVERIE Chris - TRUONG-ALLIE Guillaume

Group 3. JACQUET Quentin - DAHOUMANE Ryan - BOFFO Mathias

Group 4. DUPONT Marie - PERRAUDIN Max - SOLE Paul

Group 5. LEMAIRE Guillaume - JOHANSSON Rodolphe - DA SILVA Victor

Group 6. GIRARD Loic - MEUNIER Hugo - RUBINO-MOYNER Baptiste

Group 7. MORAGAS GARCIA Paloma - JANIN Lucas - BUSSIERE Paul

Group 8. RONDEY Julien - FITTIPALDI Maxime - MALLACH Lucas

Group 9. PILADELLI Hugo - MELEY Juliette - SYLVESTRE Sacha

Group 10. COMARLOT Nathan - BOUIX Ossian - DEFOSSE Adrien

Group 11. BARBAGALLO Nathan - AUDET Yoann - BAZIN Jules

Group 12. MORLET Juliette - GRAGNIC Quentin - PERDU Matthieu

Group 13. MURET Sanath - LEMAIRE Hadrien - CHANDON Clement

Group 14. DE LEUSSE Tanguy - RICOUART Gabin - PORRAS Fabien

Group 15. CAP Etienne - ETIENNE Louis - GUITTON Thomas

Group 16. LE BERRE Manon - ROBIN Amauri - PIOLA Raphael

Group 17. LE CORRE Francois - HALGAND Brieuc - CAMINCHER Etienne

Group 18. UTHAYANATHAN Anithigan - MORIN Mathis - CAZENEUVE Dorian

Group 19. GARCIA Laura - CALKA Magdalena - PICHON Corentin