

# MORABA Sounding Rocket Launch Vehicles

Mobile Rocket Base German Aerospace Center





# Sounding Rocket Launch Vehicles

# 1.1. Introduction

The research vehicles offered by MORABA have been used by a wide spectrum of payloads, differing in mass, complexity and transport requirements. In order to serve the needs of any payload and transport requirement, MORABA relies on a large portfolio of rocket motors that it uses in single stage as well as stacked configurations. MORABA constantly strives to enhance the portfolio of active rocket motors in order to improve its transport capacities or replace systems that run out of stock. Although the developments in liquid, gelled and hybrid propulsion are closely followed, the high power density, operational simplicity and safety of solid rocket motors have led to their exclusive use by MORABA so far.

A large portion of the active portfolio is formed by motors with military heritage. These motors are conceded to MORABA or its partners from governments that tear down a fraction of their armory. As usually these motors have exceeded their shelf life, inspection and re-lifing efforts become necessary. Many successful missions prove the flight worthiness of these motors which are not least attractive due to their competitive price.

The second group of the portfolio is made up by motors available from third parties. Here, MORABA is constantly evaluating potential candidates. A longstanding cooperation with the Brazilian Department of Aerospace Science and Technology (DCTA) has led to frequent use of its S<sub>31</sub> and S<sub>30</sub> rocket motor stages. At current, MORABA is also developing a solid motor stage with Bayern Chemie GmbH and acquiring some units of Magellan's Black Brant V.

While the majority of payloads served put 70-500kg on the scales, MORABA has also launched heavier ones and currently designs missions involving payloads up to 2to. The vehicle to accommodate such masses is developed in cooperation with DCTA.

To minimize the launch cost, passive stabilization and separation systems are implemented where ever possible. However, if requirements regarding impact dispersion or trajectory insertion accuracy necessitate trajectory control, MORABA can implement cold gas attitude and thrust vector control systems.

# 1.2. Vehicle Portfolio and Performance Capacity

The graph below illustrates significant members of MORABA's current rocket family.



Figure 1 MORABA Sounding Rocket Portfolio. The VS-40 is currently not available. The VS-50 is in development Phase D.

The graphs below and the following subsections detail out the apogee performance of MORABA's vehicles as function of payload mass. Hypersonics or re-entry research trajectories are also possible but not displayed here due to their diversity – the apogee performance however is also a good comparative measure for the performance of a vehicle when launched onto a hypersonics research trajectory. To convert apogee performance into potential microgravity research duration, Figure 4 can be used.



Figure 2 MORABA Sounding Rocket Portfolio Performance (without VS-50)



Figure 3 MORABA Sounding Rocket Porfolio Performance (with VS-50)



Figure 4 Time spent above 90/100km versus Apogee



# 1.3. Improved Orion

# 1.3.1. General

The Improved Orion is a single stage vehicle based on a demilitarized MIM-23 HAWK surface to air military surplus motor. In its simplest configuration, the 14" diameter rocket motor is fitted with three fins to sufficiently stabilize a payload of the same diameter. Motor and tailcan section weigh 420kg and measure 2.8m in length. A three fin boat tailcan and retractable launch lugs warrant minimum loss of performance due to drag. Fin incidence is used to impart a final spin rate of around 3Hz in the interest of flight path accuracy.



Figure 5 Improved Orion launch ready



# 1.3.2. Performance



Figure 6 Improved Orion Performance (based on 3-Fin 14" payload configuration and 85° launch elevation). "P/L Mass" refers to all mass ahead of the motor forward flange

The motor offers a 25s duration burn time structured in a high thrust boost phase with typical maximum accelerations in excess of 20g and a subsequent low thrust sustainer phase.

## 1.3.3. Payloads

The vehicle has been in use to carry light payloads to the edge of space conducting atmospheric and short duration milli-*g* research and as a Range Test Vehicle in preparation of other missions. While a payload diameter exceeding the 14" motor diameter can in principle be supported, the high velocities this vehicle reaches in low atmosphere due to its high initial thrust recommends slender payloads to minimize drag loss. Typical payload weights range between 50 to 120kg. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems.



# 1.4. Improved Malemute

## 1.4.1. General

The Improved Malemute military surplus motor closes the performance gap between the frequently used Improved Orion rocket motor and the larger motors of Brazilian production. In a joint effort with Andøya Space Center (ASC) and NASA Sounding Rocket Program Office, MORABA qualified this new rocket motor as a single stage launch vehicle in 2016. Including the tailcan and motor adapter sections, the motor system measures 3.5m in length. To minimize drag loss during atmospheric flight, a boat tailcan and retractable launch lugs are implemented. Due to the aggressive thrust profile of the motor, considerable aerodynamic heating occurs and is borne by thermally protected fin and motor adapter structures. Fin incidence is used to impart a final spin rate of around 3Hz in the interest of flight path accuracy.



Figure 7 Imp. Malemute ready for launch (Credit ASC)



#### 1.4.2. Performance

The motor offers a medium burn duration of sustained high thrust level, thereby reaching maximum accelerations in excess of 25g.



Figure 8: Improved Malemute Performance (based on 3-fin configuration and 85° launch elevation). "P/L Mass" refers to all mass ahead of the motor forward flange

## 1.4.3. Payloads

With its 16" main diameter, the motor typically accommodates 14" payloads but can also support 17" as a hammerhead configuration. Typical payload weights will range from 150kg to 250kg. While the heavier end of the spectrum has been occupied by atmospheric physics research, the lighter may also be used for payloads seeking medium duration microgravity conditions. The performance is also sufficient to support hypersonics research. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems.



# 1.5. VS-30

#### 1.5.1. General

The S<sub>3</sub>o rocket motor was developed as a sounding rocket vehicle by the Brazilian Department of Aerospace Science and Technology (DCTA). It was designed to meet the needs of the sounding rocket community and can serve a wide range of payloads. Fin sets of different planform area are available to meet acceptable stability margins for any payload. Including fin section, the rocket motor measures 4.3m in length and weighs 1250kg, of which 900kg are net explosive mass. Fin incidence is used to impart a final spin rate of around 3Hz in the interest of flight path accuracy.



Figure 9 VS-30 (Angicos, Credit DCTA)



# 1.5.2. Performance

The S<sub>3</sub>o rocket motor delivers 2<sub>5</sub>s of sustained medium thrust level, thereby finding a remarkable compromise that keeps both impact point dispersion and atmospheric drag losses small. Maximum acceleration is 14*g* 



Figure 10: VS-30 Performance Chart (based on a 3 fin configuration, 14" diameter payload and 85° launch elevation). "P/L Mass" refers to all mass ahead of the motor forward flange

## 1.5.3. Payloads

With its 22" main diameter, the S30 can accommodate for a wide range of payload geometries. Considerable aerodynamic heating occurs during the ascent and can be captured by thermal protection layers on relevant structures. Typical payload weights range from 150kg to 350kg. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems.



# 1.6. VSB-30

## 1.6.1. General

The VSB-30 constitutes the work horse of the German and Brazilian sounding rocket activities. High performance capacity is obtained by a simple vehicle concept thereby keeping cost reasonably low. This was achieved by developing a booster stage for the previously existing S30 in a joint effort by the Brazilian Department of Science and Technology (DCTA) and the German Aerospace Center DLR. Called S31, this booster stage was designed using many of the features and manufacturing techniques used in the S30 program, but trimmed to deliver a high initial thrust necessary to meet the stringent impact dispersion requirements of ESRANGE, Sweden. Three solid rocket spin motors accommodated in the interstage adapter support the mitigation of dispersion by imparting a vehicle roll right after launcher exit. Fin incidence is used to further improved trajectory accuracy and imparts a final spin rate of around 3Hz. The first stage is drag separated upon burnout. To optimize performance, the second stage is usually ignited shortly after separation, but also longer coast phases are possible to obtain a suppressed trajectory meeting the interests of hypersonics research. Including tailcan sections, interstage and motor adapter, the rocket motor system measures 7.3m and weighs 2.2to of which 700kg (S31) and 900kg (S30) are net explosive mass.



Figure 11: Payload during loading onto a VSB-30 in the Skylark Launcher at ESRANGE, Sweden



# 1.6.2. Performance

The combination of the aggressive S<sub>31</sub> booster and the enduring S<sub>30</sub> sustainer stages yields high payload performance while keeping the maximum acceleration down to as low as 1<sub>3</sub>g.



Figure 12: VSB-30 Performance (based on 3-3 fin configuration, 17" payload diameter and 85° launch elevation). "P/L Mass" refers to all mass ahead of the motor forward flange.

# 1.6.3. Payloads

With its 22" main diameter, the VSB-30 accommodates a wide range of payloads. Even hammerhead payloads have been successfully flown. Typical payload weights range from 350 to 450kg. Payload lengths up to 5.3m have been supported. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems.



# 1.7. VS-31 / Improved Orion

# 1.7.1. General

To suit the needs of payloads of moderate mass, but high altitude requirement, the VS-31 / Improved Orion was developed. Utilizing the 400kg light military surplus Improved Orion Motor and a passive drag separation system, the powerful S31 Booster delivers high initial acceleration which allows to omit the use of spin motors as required for the VSB-30 e.g. The vehicle is therefore very cost effective. It is usually launched in 4-4 fin configuration and measures 6.3m from top of motor adapter to end of S31 tailcan. Fin incidence is used to impart a final spin rate of around 2.5Hz in the interest of flight path accuracy.



Figure 13: S31 / Improved Orion leaving the launcher at ESRANGE, Sweden



# 1.7.2. Performance

To maximize the apogee performance, the Improved Orion is fired seconds after burn out and drag separation of the S<sub>31</sub> booster. A maximum acceleration of 16*g* is reached during the high thrust phase of the Improved Orion.



Figure 14: S<sub>31</sub> / Improved Orion Performance (based on 4-4 fin configuration, 14" diameter payload and 85° launch elevation). "P/L Mass" refers to all mass ahead of the motor forward flange

# 1.7.3. Payload

The vehicle can accommodate payloads up to 17" diameter. It has been used to support atmospheric physics research, but may also be used for lightweight, long duration microgravity or hypersonics research missions. Typical payload weights range from 150kg to 300kg. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems.



# 1.8. VS-30 / Imp. Orion

# 1.8.1. General

The VS-30 / Improved Orion is the stronger brother of the VS-31 / Improved Orion. Using the larger S30 in lieu of the S31 as a booster allows for even more performance. The vehicle qualifies to put light to medium mass payloads to a high speed or high altitude. As both the high vehicle performance and the – compared to the S31 – modest initial thrust of the S30 enlarge the impact point dispersion, the vehicle requires a large impact area allowing for a 3-sigma dispersion estimate >60km in radius.



Figure 15 VS-30 / Improved Orion on the JAXA launcher in Woomera, Australia (Credit DST Group)



# 1.8.2. Performance

To maximize apogee performance, the Improved Orion is fired seconds after burn out and drag separation of the S<sub>3</sub>0 booster. Maximum acceleration is found during the high thrust burn phase of the Improved Orion and amounts to around 16*g*.



Figure 16: S<sub>30</sub> / Improved Orion Performance (based on 4-4 fin configuration, 14" diameter payload and 8<sub>5</sub>° launch elevation). "P/L Mass" refers to all mass ahead of the motor forward flange

# 1.8.3. Payloads

The vehicle can accommodate payloads up to 17" diameter. Typical payload weights range 150kg to 300kg. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems.



# 1.9. S31 / Improved Malemute

# 1.9.1. General

To utilize the Improved Malemute military surplus motors for high performance microgravity missions, a configuration boosted by an S<sub>31</sub> was developed and successfully launched in 2018. The system features a passive stage separation. Even though high apogees can be reached, the system does not require the use of a spin motor system as the lightweight Improved Malemute and the powerful S<sub>31</sub> booster warrant high launch acceleration thereby limiting the dispersion estimate. Fin incidence is used to further improve the flight path accuracy. A final spin rate of 2.5Hz is reached upon second stage burn out.



Figure 17: S31 / Improved Malemute stages and payload fully assembled



# 1.9.2. Performance



Maximum acceleration is reached at second stage tail-off thrust and amounts to 24g.

## 1.9.3. Payload

With the 16" motor diameter of the Improved Malemute upper stage, the vehicle can support payload diameters up to 17". Typical payload weights will range from 280kg to 380kg. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems.

Figure 18: S<sub>31</sub> / Improved Malemute Performance (based on 3-3 fin configuration, 17" diameter payload and 85° launch elevation). "P/L Mass" refers to all mass ahead of the motor forward flange



# 1.10. VS-50

#### 1.10.1. General

The two stage VS-50 is a large sounding rocket to support heavy weight payloads that require insertion into extended micro-*g* duration ( > 10min) or high enthalpy (Ma > 15) trajectories. It is currently under development in Phase D in a joint project of DLR, the Department of Aerospace Science and Technology (DCTA) of Brazil and the Brazilian space agency AEB. It also serves as a major milestone in the development of the VLM-1 microsatellite launcher which is basically a boosted version of the VS-50. The thrust vectored first stage of the VS-50 is called S50 and features a carbon fiber reinforced motor case containing 12to of composite propellant. Its main diameter is 1.5m. The flight proven S44 is used as second stage and controlled in attitude by a cold gas system to warrant flight path accuracy. The vehicle is launched from a dedicated launch stool.



Figure 19 VS-50 and first stage thrust vector assembly



# 1.10.2. Performance

Maximum acceleration is reached at thrust tail-off during the 85s burn phase of the first stage and amounts to 7g.





## 1.10.3. Payload

The VS-50 in single or two stage configuration can accommodate a wide range of payloads under its 5m long fairing of 1.5m diameter. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Rate and Attitude Control (mechanical and/or Cold Gas) Systems.