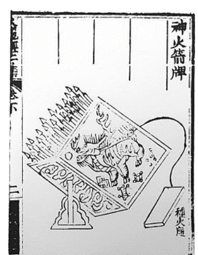
Solid Rocket Motors

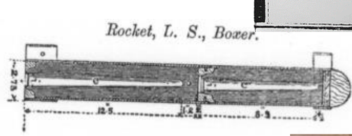
Solid Rocket Motors

- Oldest rocket technology

1941 demonstration of Jet Assisted Takeoff (JATO)



Fire Arrow launcher from 14th century Huǒ Lóng Jīng (developed before 1230)



Boxer Rocket (1855), two-stage, used for rescue operations

  - powder based propellants (black powder, amide* powder for JATO)

*no sulfur and ammonium nitrate added

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Solid Rocket Motors

- Compared to LREs

Advantages	Disadvantages
Simple (less system components)	Lower Isp
Reliable (few moving parts)	Harder to test (no subcomponent tests) and sensitive to environmental temp.
Reduced storage volume (high ρ)	Hard to actively throttle
Storable (especially compared to cryogenics)	Manufacturing defects (e.g., cracks) and degradation at extreme storage conditions
Easier to start (vs. pump fed LREs)	No restarts
Easily(?) scalable (to high and low thrust)	Emissions (HCl and chlorinated compounds) and signature (smoke) for popular propellants

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Solid Rockets - Major Applications

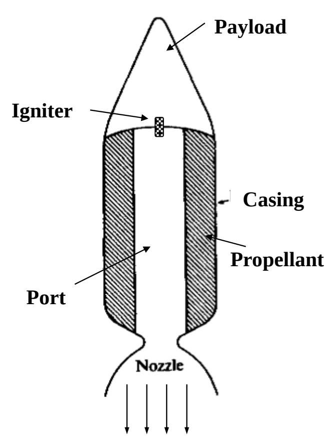
- **High thrust**
  - boosters
  - high acceleration missiles
- **Simplicity, storability**
  - hobbyists, weapons systems
  - novel programmable micro-thrusters

Solid Rocket Motors

Components and Configurations

SRMs: Nomenclature

- Basic parts of a solid rocket motor (SRM)
  - casing (and insulation)
  - propellant (grain)
  - port/bore (not for end burning)
  - igniter
  - payload
  - nozzle



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SRM Components: ASRM

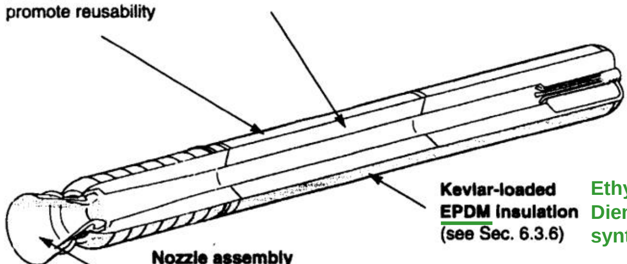

Fig. 6.2. **Schematic of ASRM (Advanced Solid Rocket Motor).** Courtesy of Aerojet Corporation.

From Humble

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SRM Components: Pegasus

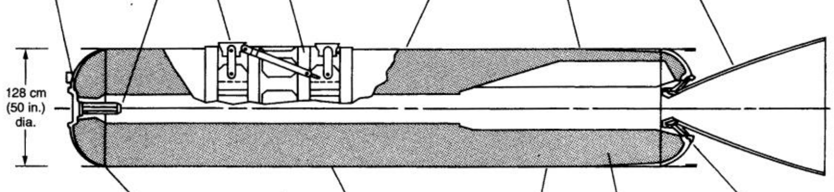
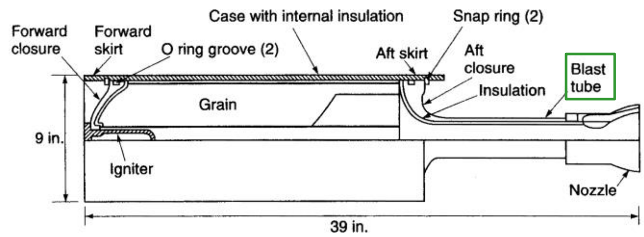


FIGURE 11–2. Booster rocket motor for the Pegasus air-launched three-stage satellite launch vehicle. It has a cylinder grain cavity with fins. The 50 in. diameter case has structural reinforcements to attach the Pegasus vehicle to its launch airplane and also to mount a wing to the case. It produces a maximum vacuum thrust of 726 kN (163,200 lbf) for 68.6 sec, a vacuum specific impulse of 295 sec, with a propellant mass of 15,014 kg and an initial mass of 16,383 kg. (Courtesy of Orbital Sciences, Corp. and Alliant Tech Systems.)

From Sutton

SRM Configurations: Tactical Motor



for flight stability

FIGURE 11–4. Simplified cross section through a typical tactical motor. The blast tube allows the grain to be close to the center of gravity of the vehicle; there is very little movement of the center of gravity. The nozzle is at the missile's aft end. The annular space around the blast tube is usually filled with guidance, control, and other non-propulsive equipment. A free-standing grain is loaded before the aft closure is assembled.

From Sutton

SRM Configurations: Launch Booster

Titan IV

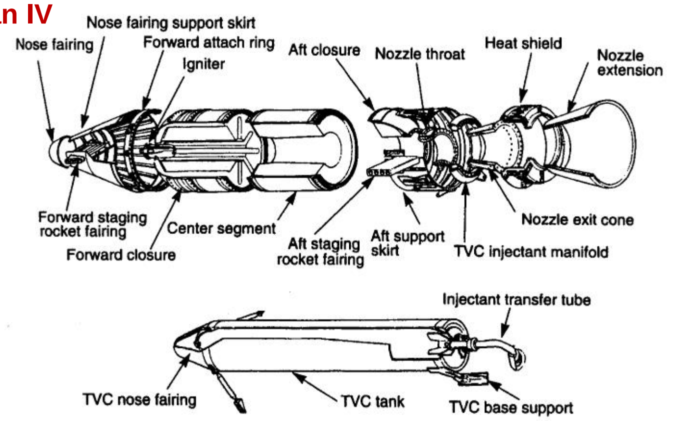
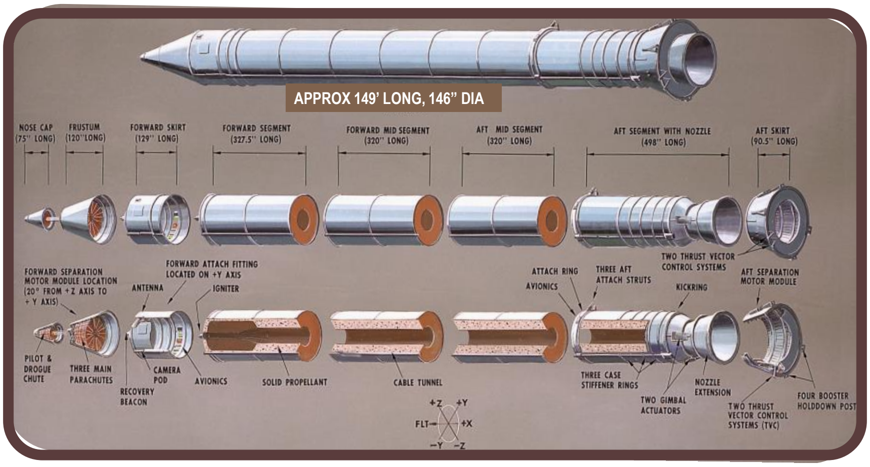


Fig. 6.3. Schematic of Titan IV Motor. (TVC = Thrust Vector Control) Courtesy of United Technologies Chemical Systems.

From Humble

Space Shuttle SRB



from nasa.gov

SRM Configurations: Launch Booster

GEM: Delta rockets, Atlas V, Vulcan

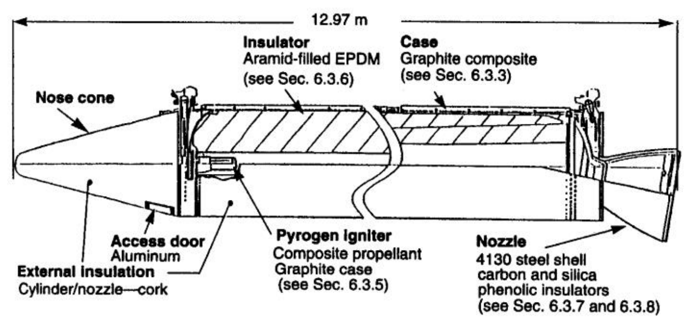


Fig. 6.4. Schematic of GEM (Graphite Epoxy Motor). Courtesy of Hercules Aerospace Company.
GEM 46 now Orbital ATK

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SRM Configurations: In-Space Motors

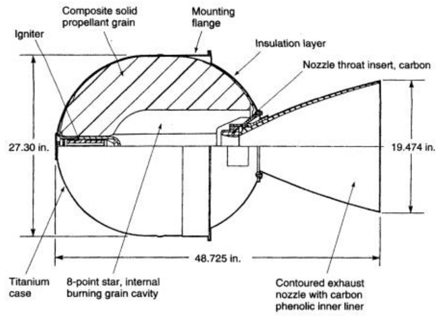

FIGURE 11–1. Cross section of the STAR^{TM} 27 rocket motor, which has been used for orbit and satellite maneuvers. It has an altitude thrust of 6000 lbf, nominally burns for 34.4 sec and has an initial mass of 796 lbm. For more data see Table 11–3. (Courtesy of Thiokol Propulsion, a Division of Cordant Technologies.)

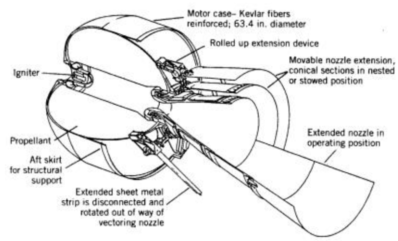

FIGURE 11–3. Inertial upper stage (IUS) rocket motor with an extendible exit cone (EEC). This motor is used for propelling upper launch vehicle stages or spacecraft. The grain is simple (internal tube perforation). With the EEC and a thrust vector control, the

STAR (apogee kick motor): CTS, GMS, BS, GPS, GOES satellites

Inertial Upper Stage (IUS): used in Titan, Space Shuttle launches