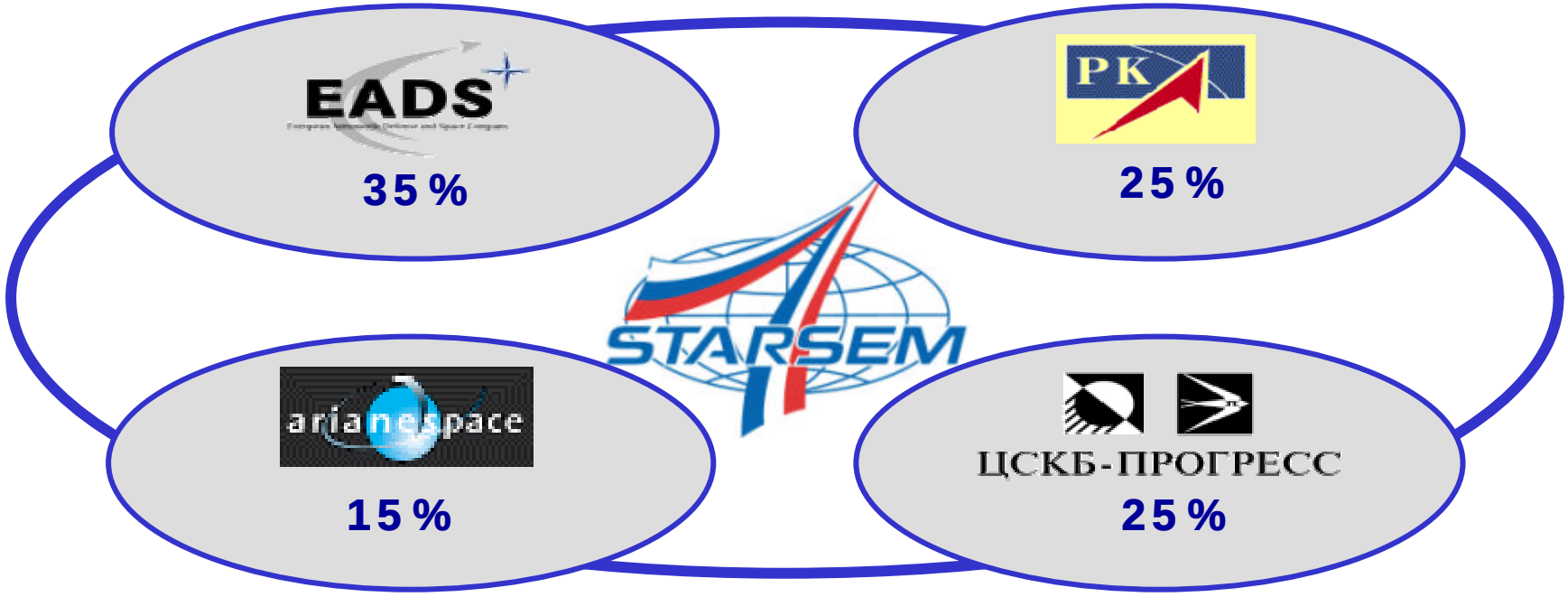
RD-0124
AN OPTIMIZED PROPULSION SYSTEM FOR Soyuz/ST

Versailles, May 14,2002

STARSEM
The Soyuz Company

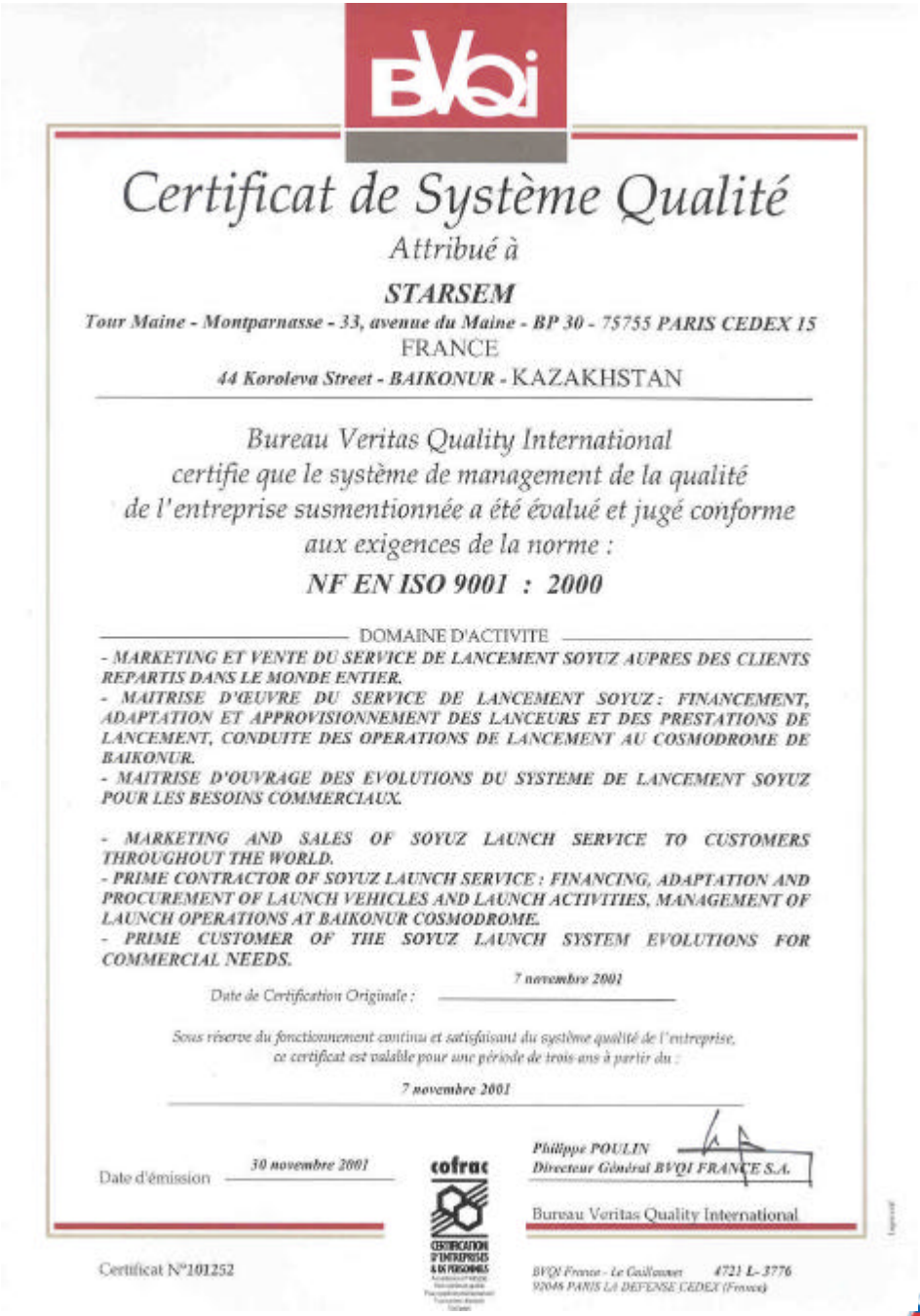
Starsem Organization



50-50 European-Russian joint venture providing Soyuz launch services for the commercial market

ISO 9001 Certification

Starsem has been certified ISO 9001:2000 since November 2001



BVQI

Certificat de Système Qualité

Attribué à

STARSEM

Tour Maine - Montparnasse - 33, avenue du Maine - BP 30 - 75755 PARIS CEDEX 15
FRANCE

44 Koroleva Street - BAIKONUR - KAZAKHSTAN

Bureau Veritas Quality International
certifie que le système de management de la qualité
de l'entreprise susmentionnée a été évalué et jugé conforme
aux exigences de la norme :

NF EN ISO 9001 : 2000

DOMAINE D'ACTIVITE

- MARKETING ET VENTE DU SERVICE DE LANCEMENT SOYUZ AUPRES DES CLIENTS REPARTIS DANS LE MONDE ENTIER.
- MAITRISE D'ŒUVRE DU SERVICE DE LANCEMENT SOYUZ : FINANCEMENT, ADAPTATION ET APPROVISIONNEMENT DES LANCEURS ET DES PRESTATIONS DE LANCEMENT, CONDUITE DES OPERATIONS DE LANCEMENT AU COSMODROME DE BAIKONUR.
- MAITRISE D'OUVRAGE DES EVOLUTIONS DU SYSTEME DE LANCEMENT SOYUZ POUR LES BESOINS COMMERCIAUX.

- MARKETING AND SALES OF SOYUZ LAUNCH SERVICE TO CUSTOMERS THROUGHOUT THE WORLD.
- PRIME CONTRACTOR OF SOYUZ LAUNCH SERVICE : FINANCING, ADAPTATION AND PROCUREMENT OF LAUNCH VEHICLES AND LAUNCH ACTIVITIES, MANAGEMENT OF LAUNCH OPERATIONS AT BAIKONUR COSMODROME.
- PRIME CUSTOMER OF THE SOYUZ LAUNCH SYSTEM EVOLUTIONS FOR COMMERCIAL NEEDS.

Date de Certification Originale : *7 novembre 2001*

Sous réserve du fonctionnement continu et satisfaisant du système qualité de l'entreprise, ce certificat est valable pour une période de trois ans à partir du :

7 novembre 2001

Date d'émission *30 novembre 2001*

cofrac

Philippe POULIN
Directeur Général BVQI FRANCE S.A.

Bureau Veritas Quality International

Certificat N°101252

BVQI France - Le Guillaumet 4721 L- 3776
92046 PARIS LA DEFENSE CEDEX (France)

STARSEM

Soyuz Milestones

1961: Y. Gagarin - First man in space

1957: Sputnik - First Satellite

1999: Globalstar - First Starsem flights

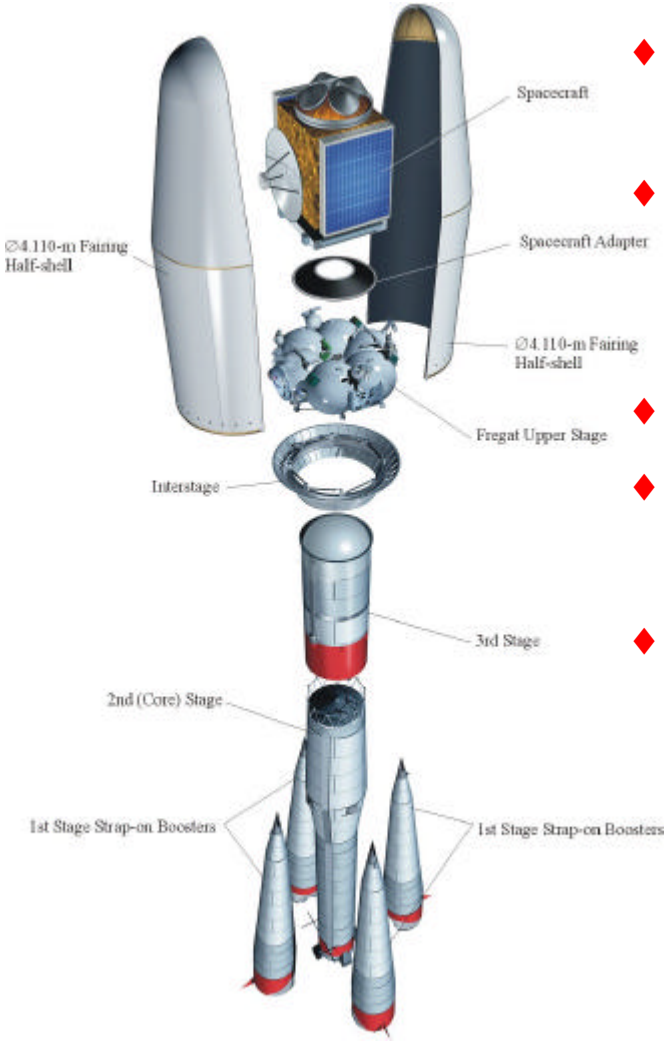
2000: Cluster II flights

2000: First Crew to ISS

2001: Flight qualification of upgraded FG engines

- 1669 launches
- Sustained production
- Stepwise performance enhancements
- Unmatched reliability

Overview



- FG engines for 1st and 2nd stages: flight proven
- Digital control system: first flight mid-03

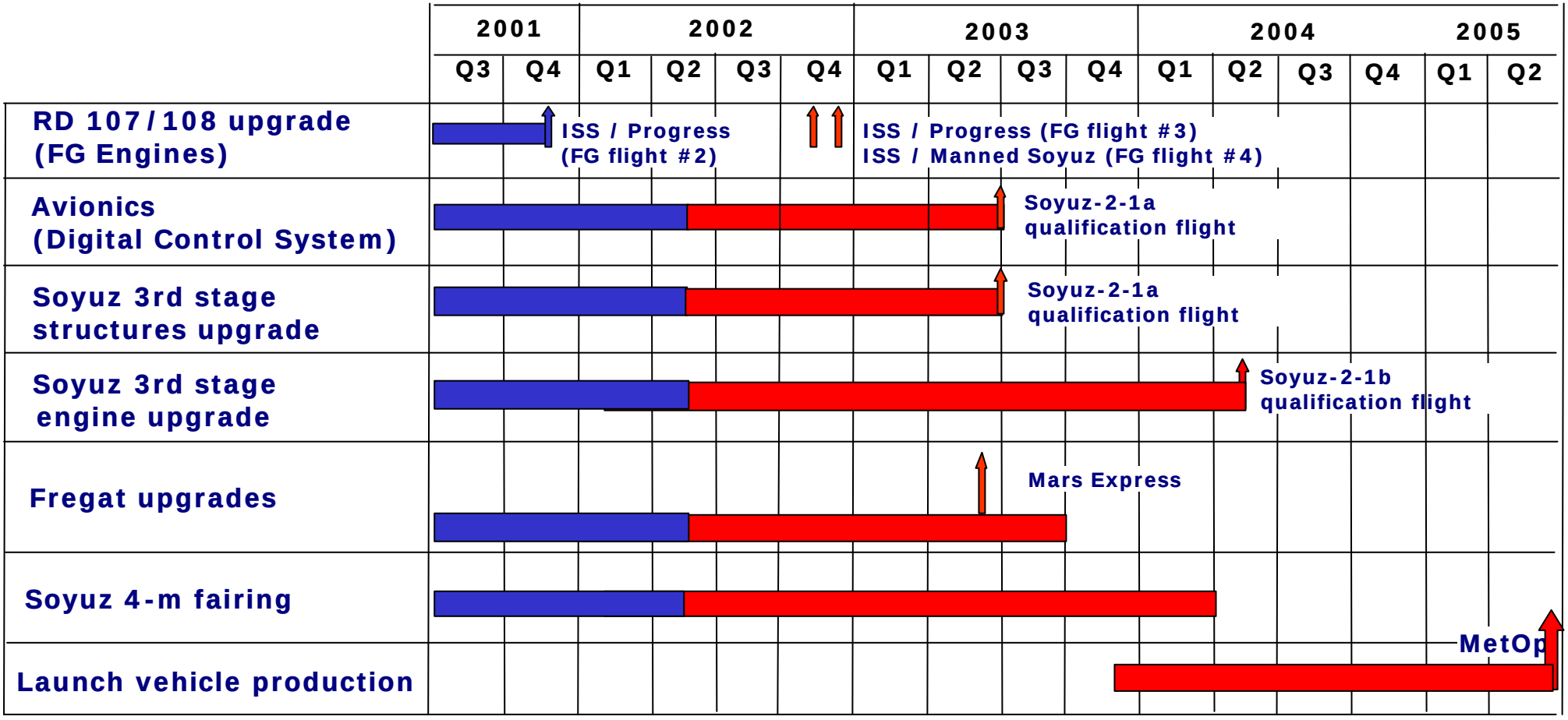
} Soyuz-2-1a

- ST fairing (Æ 4.11m, L 11.4m)
- Fregat upper stage upgrades

- Third stage engine upgrade available 3Q04

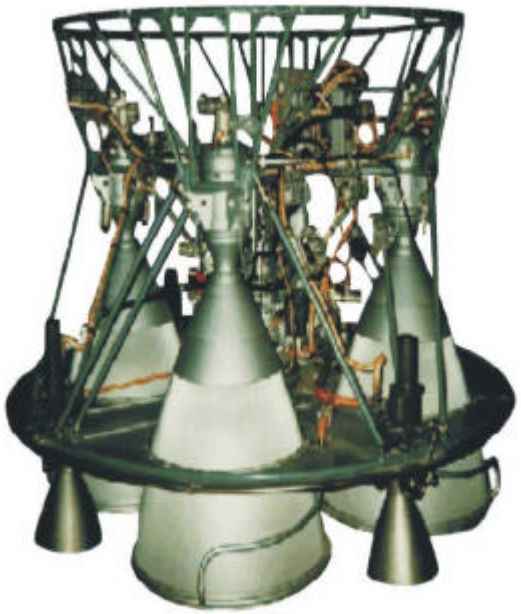
} Soyuz-2-1b

Soyuz/ST Development schedule




Third Stage Presentation

Third Stage Engine



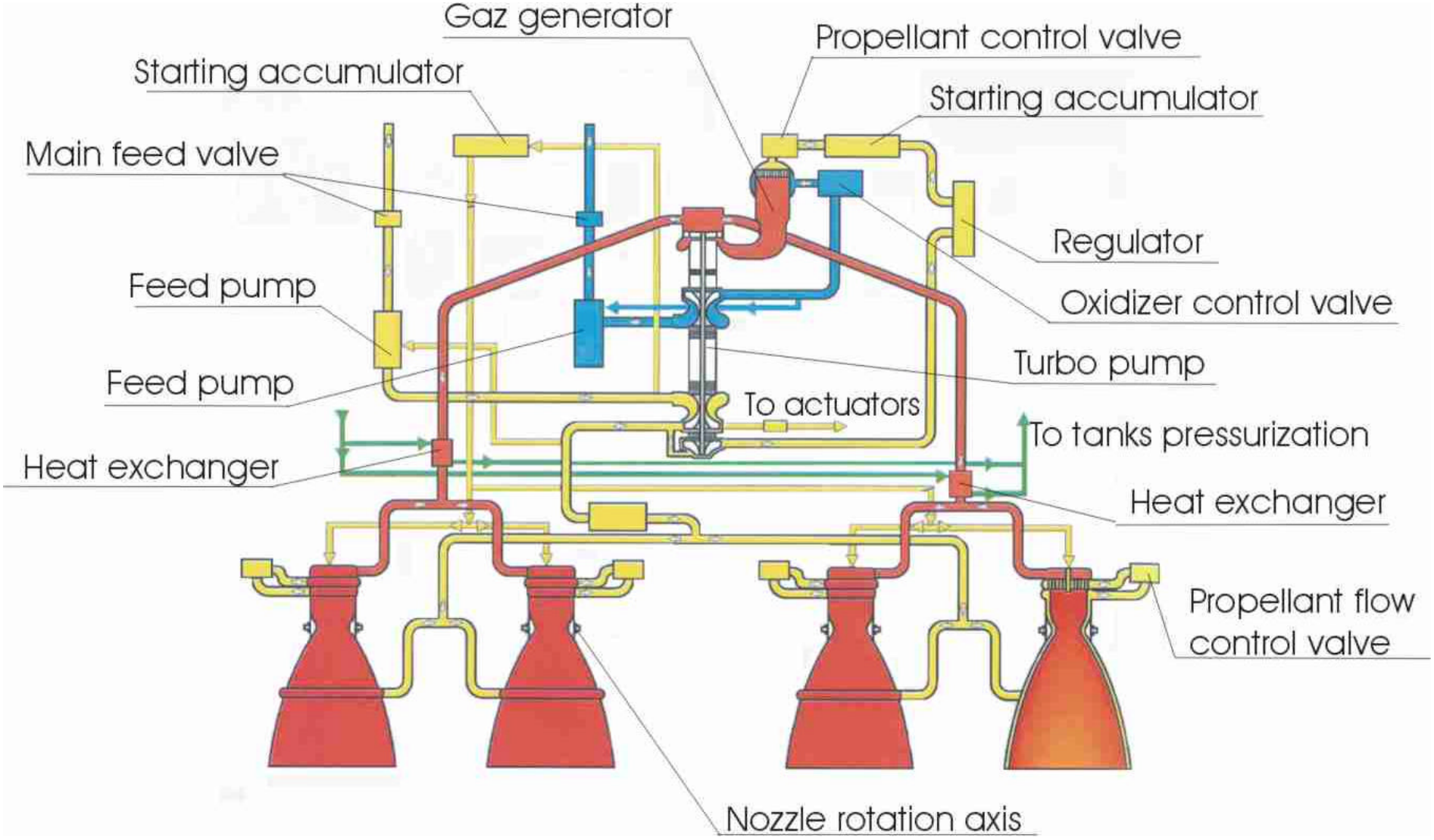
- **RD-0124 engine will replace the currently used RD-011O:**
  - **Staged combustion cycle (compared to open cycle)**
  - **4 gimbaled (1 axis) combustion chambers**
  - **Kerosene derivation for actuators feeding**
  - **Sequenced shut-down to reduce transient loads on the stage**

Engine Principles and Heritage

- **Development by KBxhA Company, located in Voronezh with a strong backing experience:**
  - **LOX/Kerosene (RD-0110 for existing Soyuz third stage)**
  - **UDMH/N2O4 (RD-0210 & RD-0212 for Proton second stage)**
  - **LOX/Hydrogen (RD-120 for Energia first stage)**

- **Staged combustion cycle based on LOX/LH2 & UDMH/N2O4 engines:**
  - **Two stage fuel pump and single stage oxygen pump**
  - **High pressure fuel pump**
  - **Feeding pumps for kerosene and liquid oxygen**
  - **Oxygen rich preburner**

Engine Layout



Engine Main Characteristics

- Chamber pressure: 15,69 Mpa
- LOX pump pressure: 36,3 MPa
- Fuel pump pressure: 36,3 Mpa / 47,1 MPa
- Turbine inlet pressure: 319 bar
- Turbine outlet pressure: 185 bar
- Turbine temperature: 973 K
- LOX mass flow rate: 56,7 kg/s
- Fuel mass flow rate: 23,9 kg/s
- Mixture ratio: 2,34
- Specific impulse: 357 sec
- Thrust: 294,2 kN
- Shut-down regime: 146,9 kN

Engine Qualification (1/2)

- **Qualification philosophy based both on progressive element testing with a large number of engines and extensive hot-fire test program:**
  - **Combined main turbine and preburner tests without combustion chambers**
  - **Addition of feed pumps**
  - **Stepped introduction of combustion chambers (up to 4)**
  - **As of April 2002, 62 tests were performed:**
    - 4 complete engines fired (with 4 chambers)
    - 7273 s cumulative firing duration
    - 742 s with same engine (300 s continuous)
  - **49 tests still to be performed:**
    - Nominal duration/nominal parameters
    - Increased duration
    - Parameter deviation

Engine Qualification (2/2)

- **Final qualification test by manufacturer**
  - based on 2 engines manufactured according to final definition
  - 4 firing tests using nominal condition parameters
- **Independent ground qualification (Flight authorization):**
  - based on 3 more similar engines
  - 6 firing tests using nominal condition parameters
  - Performed under the control of Keldysh Russian Academy
- **Once qualified, production will be monitored through permanent sampling of production engines:**
  - to confirm design reliability
  - to consolidate statistic database
  - for manufacturing quality control

Driving Parameters for Stage Design (1/3)

- **Interchangeability with RD-0110 engine**
  - **identical thrust (294.2 kN with shut-down regime at 146,9 kN)**
  - **identical mechanical interfaces with third stage**
  - **identical tank pressurization level (LOX = 4,75 bar, K = 2,5 bar)**

- **Specific impulse = 357 s (compared to 325 s)**
  - **leads to increased burn duration (274 s, compared to 254 s)**

- **Mixture ratio = 2.34 (compared to 2,22)**
  - **tanks volume modification:**
    - increased cylindrical section for LOX tank (850 to 1046 mm)
    - hemispherical vessel replaces Ø2660 spherical tank for kerosene

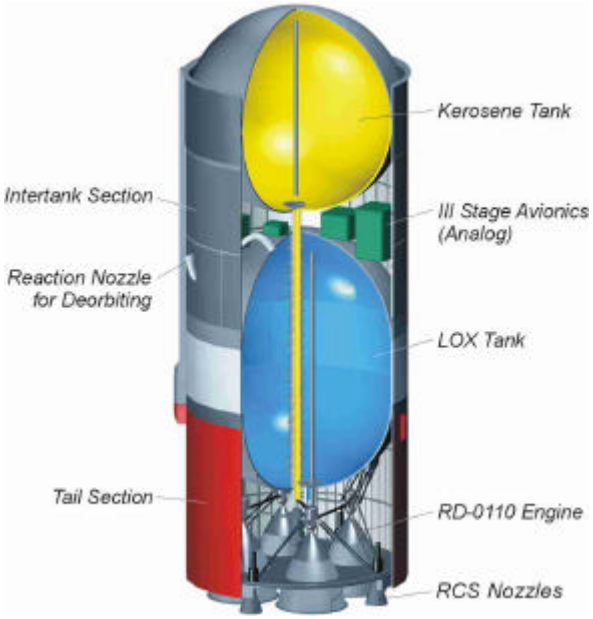
Driving Parameters for Stage Design (2/3)

- **Fuel and oxidizer tank pressurization:**
  - **RD-0110: cooled gases derived from gas generator**
  - **RD-0124: based on 5 helium vessels located into the LOX tank**

- **Control system identical to RD-0110 version:**
  - **RD-0110: managed through digital control system**
  - **RD-0124: identical to RD-0110 with S/W adaptations and upgraded command units**

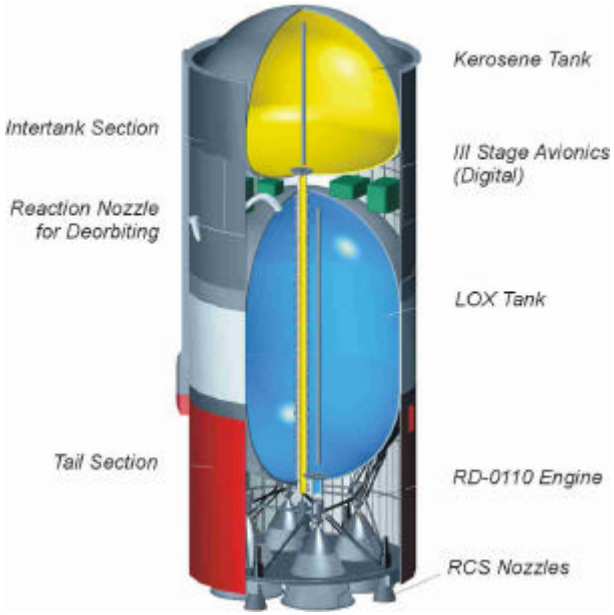
- **Attitude control:**
  - **RD-0110: rotation of 4 exhaust nozzles (±45° around one axis)**
  - **RD-0124: rotation of each main chamber (±3.5° around one axis)**

Driving Parameters for Stage Design (3/3)

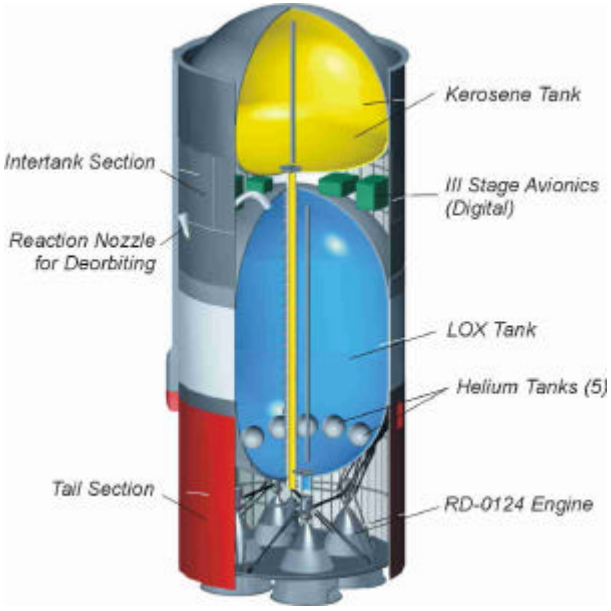


RD-0110

Current Soyuz



RD-0110



RD-0124

Upgraded Soyuz

Structures and Stage Layout Qualification

- **Qualification of tanks and stage modifications is made using current engine version to authorize 2Q03 first launch:**
  - **Static test sequence completed**
  - **Dynamic tests with equipment mass mock-ups & RD-0110 engine completed**

- **Stage upper skirt reinforcement for Æ 4.11 m fairing design loads (2 testing stages) :**
  - **Dynamic test sequence with new engine and components (RD-0124, helium tanks,...)**
  - **Limited static test sequence on a new reinforced third stage**
  - **Reinforced design applied for 2Q03 launch**

- **Integration tests with new engine and components:**
  - **validation of equipment overall layout (actuators, harness, etc...)**

Stage Functional Qualification

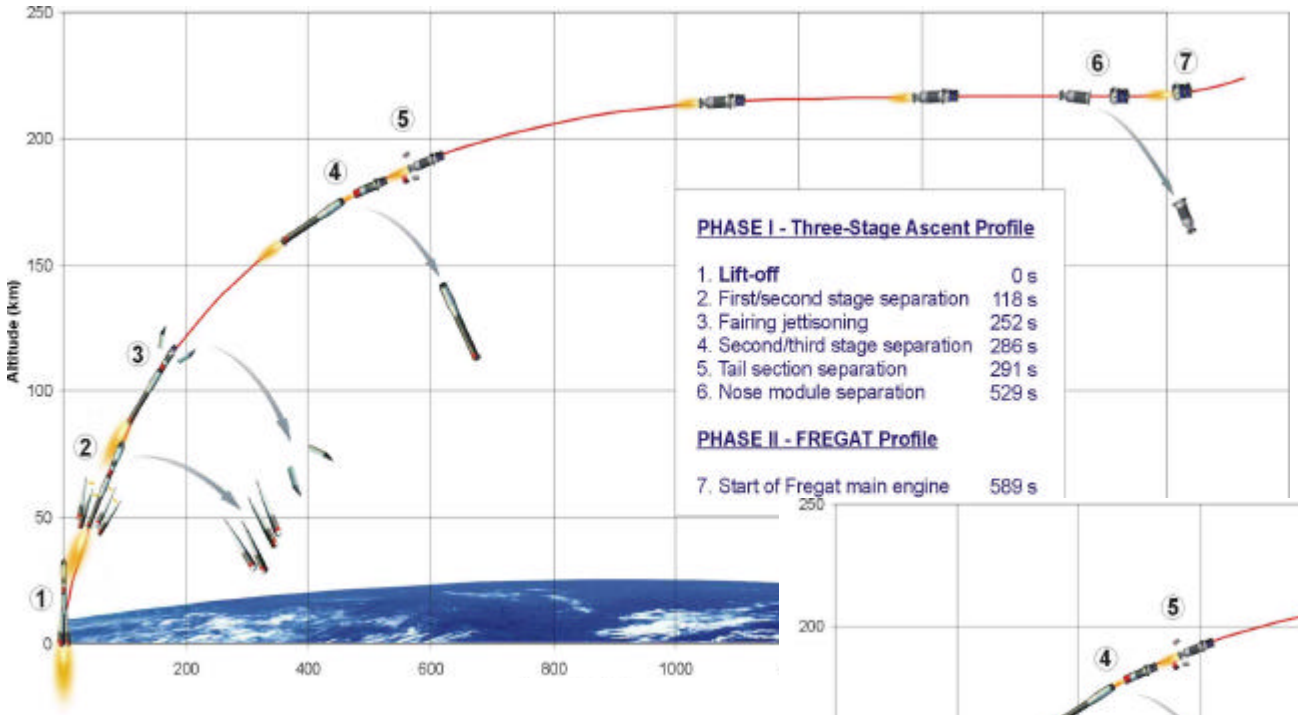
- **Cold test sequence to qualify ground preparation and procedures:**
  - **Tank filling and drainage,**
  - **Helium pressurization system,**
  - **Stage and engine mock-up are available.**

- **Hot test sequence to qualify third stage overall performance:**
  - **3 firing tests of assembled stage with engine and sub-systems,**
  - **Nominal flight duration (274 s),**
  - **Utilization of live control system,**
  - **Utilization of on-board pressurization system,**
  - **Utilization of on-board engines activation units.**

Final stage readiness for launch will be authorized after successful completion of the 3 hot-fire tests


Mission Profile and
Performance

Soyuz Ascent Profile (Baïkonur)

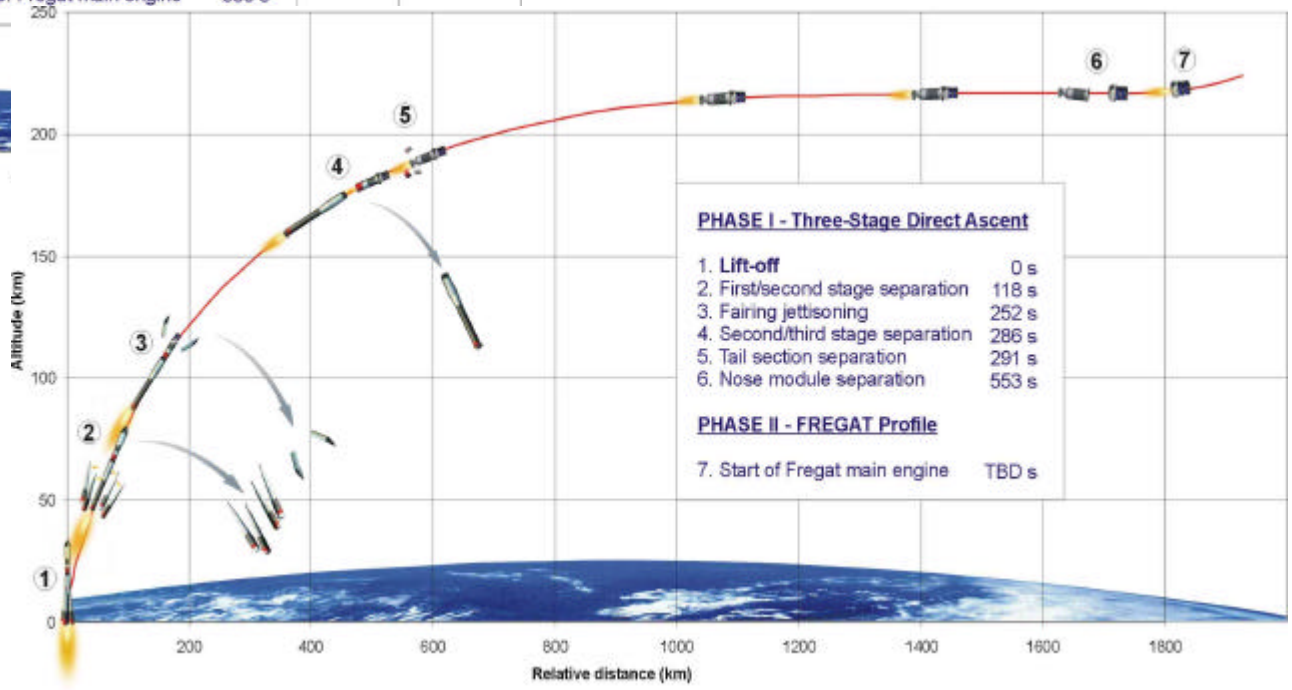


PHASE I - Three-Stage Ascent Profile

1. **Lift-off**	0 s
2. First/second stage separation	118 s
3. Fairing jettisoning	252 s
4. Second/third stage separation	286 s
5. Tail section separation	291 s
6. Nose module separation	529 s

PHASE II - FREGAT Profile

7. Start of Fregat main engine	589 s



PHASE I - Three-Stage Direct Ascent

1. **Lift-off**	0 s
2. First/second stage separation	118 s
3. Fairing jettisoning	252 s
4. Second/third stage separation	286 s
5. Tail section separation	291 s
6. Nose module separation	553 s

PHASE II - FREGAT Profile

7. Start of Fregat main engine	TBD s

Soyuz Performance (Baïkonur)

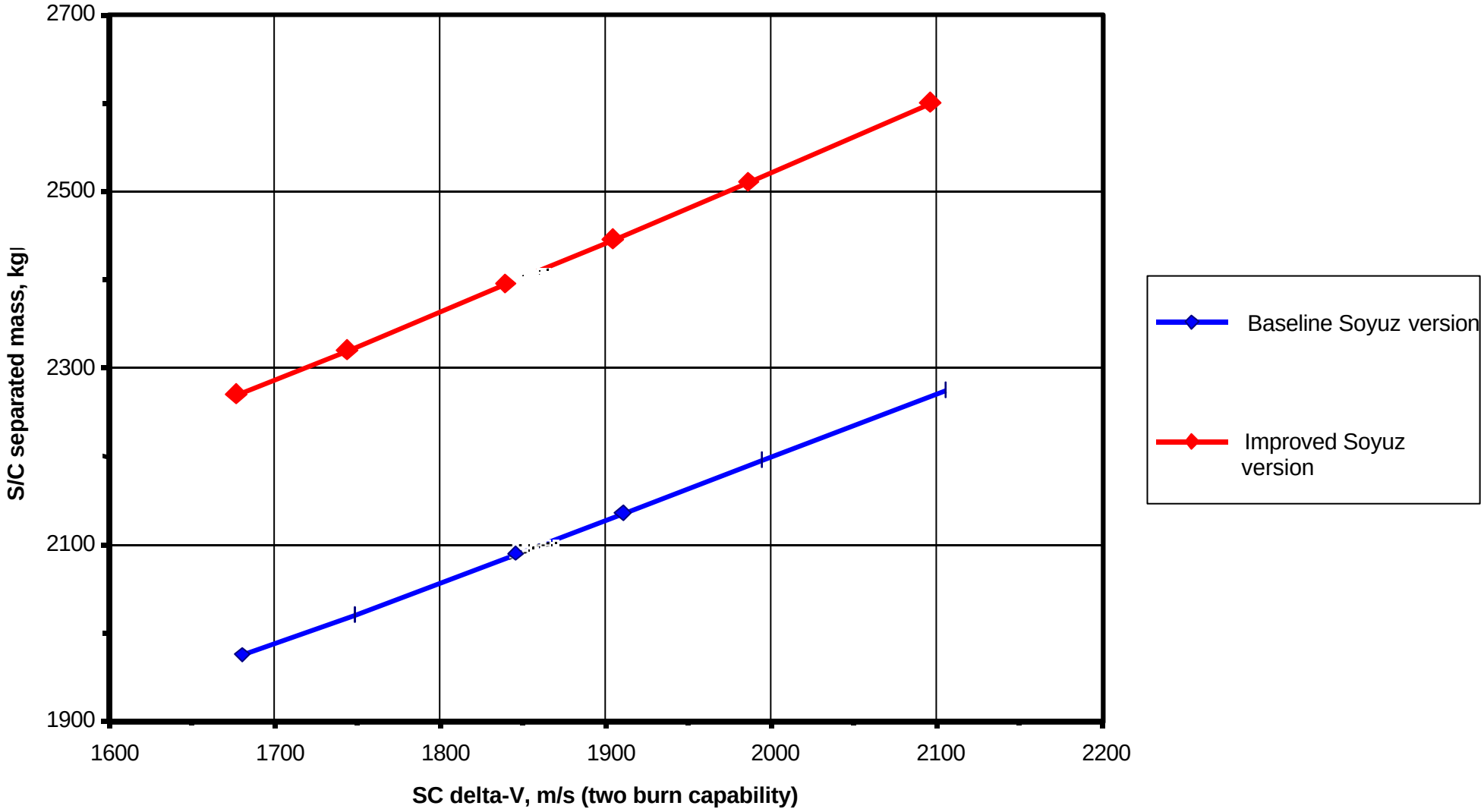
- **SSO Orbit (98,1° / 700 km)**
  - **Soyuz-2-1a: 4500 kg**
  - **Soyuz-2-1b: 4800 kg**

- **GALLILEO (56° / 23616 km)**
  - **Soyuz-2-1a: 1420 kg**
  - **Soyuz-2-1b: 1570 kg**

- **MOLNYA 12 hours (63,4° / 39100 x 1200 km)**
  - **Soyuz-2-1a: 1990 kg**
  - **Soyuz-2-1b: 2410 kg**

- **MOLNYA 24 hours (63,4° / 46340 x 25230 km)**
  - **Soyuz-2-1a: 1120 kg**
  - **Soyuz-2-1b: 1410 kg**

Soyuz Performance for GTO (Baïkonur)




Conclusion

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- **The installation of the RD-0124 engine on the third stage minimizes the impact on the Soyuz launch system design:**
  - **no modification of first and second stages**
  - **limited number of adaptation of the third stage**
  - **no modification of the launch pad**
  - **available mid 2004**
- **The RD-0124 extends the Soyuz capability on all type of orbit**
- **Thorough ground qualification provides excellent opportunity for first flight**