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**International Cooperation in Space Launch
Propulsion**

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Abstract

To date, the beginnings of cooperation in space launch propulsion have been limited in nature and commercially driven. The RD-180 program is the best example of a successful major international cooperation, with an engine produced in Russia and flown on a US launch vehicle. A truly joint propulsion system development program along the lines of a CFM56, V2500 or Joint Strike Fighter (JSF) type cooperation in the jet engine world has not yet been undertaken, although the SPW2000 program by Pratt & Whitney and SNECMA/ESA a few years ago came close.

Space launch propulsion is part of a military heritage and national interest and security culture which presents very specific challenges to overcome. International cooperation can be successful, however, the creation of substantive value for all parties is a necessary condition for any such cooperation to be successful. If this is not the case, the cooperation will fail. The most important issues to be addressed in an international teaming arrangement are communications, assured access to space, and import/export licensing.

Several examples of international cooperation in space launch propulsion are discussed, as well as the Joint Strike Fighter program which offers a new and innovative "best value" approach to international teaming on a large scale which bears significance for potential future space propulsion cooperations. It is shown that for a successful international cooperation to occur in space launch propulsion, the timing must be right, the politics must be right, and the application must be right.

Introduction

Over the last several decades, international cooperation in the field of aerospace systems has been increasing. This is especially true in the aeronautical field of airplanes and jet propulsion, but it is also true for the field of space launch. Consider Boeing's Sea Launch agreements and Lockheed Martin's arrangements for ILS. Also consider that internationally produced components are flying every flight on both the Delta IV and Atlas V launch vehicles. Another example of international cooperation dates back to the early 1970's with the VTOL Harrier airplane, the propulsion of which was co-produced for a short time in the US by Pratt & Whitney. Most recently this cooperation is reflected in the JSF program, which includes multiple international partners both for the airframe and for the propulsion.

There is one common denominator for all of these international collaborations and that is the creation of substantive value. Value takes many forms including reduced costs (non-recurring or recurring), reduced risk (technical or schedule), increased sales potential, etc. Cooperation may even be motivated by a desire to create a political environment that positively influences other parts of the business. But once again the positive secondary influences will have to be of value to all parties in some way for the arrangement to be successful.

There are many differing reasons for international cooperation, the most durable and supportable rationale being the creation of value. The most common reasons leading to international programs with substantive value creation are as follows:

- The Best Demonstrated Expertise may be in a Foreign Country (“Best Value”)
- Resource Availability
- Reduced Financial Risk (cost/schedule /technical)
- Reduced Investments
- Increased/Alternate Sales Opportunities
- New Product Opportunity
- Complementary Capabilities and Customer Base
- Partnerships formed in Response to Government Requests

This paper addresses some of the issues and success factors for international cooperation in the area of space launch propulsion, using Ariane propulsion programs in Europe and the RD-180 and the SPW2000/RL60 engine programs with US partners as examples. In addition, the Joint Strike Fighter (JSF) Program will serve as an example of a major international cooperation whose features could make it a role model for future international cooperation in space launch propulsion. For the purpose of this paper, a major cooperation in propulsion is characterized by industry teaming arrangements, which involve the design, development and production of propulsion systems. Traditional offset programs with their limited production runs will not be discussed here.

Issues and Key Factors to Consider Prior to Teaming

Experience has shown that the following issues have to be addressed early in the program exploratory stages and throughout program definition:

- Partner Relationship (Type, Roles and Responsibilities, Management, Contractual Arrangements, ...)
- Value and Measure of Financial / Non-Financial Benefit
- Management, Engineering and Quality Procedures
- Design and Data Rights
- Import/Export Regulations
- Independent / Assured Access to Space
- Protection of Industrial Base
- Government Preferences, Policies and Political Considerations
- Timing (10 - 40 year Product Life Cycles)

Once the case for substantive value has been established there are several important factors which must be addressed next in considerable detail. The three most important factors are; setting up efficient communications; ensuring national desires for independent access to space are addressed; and getting the required government licenses in order. In most cases these issues will add some cost to the program and must be considered in the overall valuation of the potential teaming arrangement.

Communications

One of the first issues that come to mind with communications are possible language differences and dealing with differences in time zones. Experience has shown that these are minor problems. For US companies, we are fortunate that most of the technical community can communicate in English. If translators are required, this usually presents only a minor inconvenience and cost (for a major program).

The most important factor with communications is ensuring that all parties understand the issues relative to the partnership or teaming. Major communications issues that need to be addressed are; a clear understanding of roles and responsibilities; the program management approach and organizational structure to be used; consistency and compatibility of engineering processes and quality processes; design rights and data rights; etc. As with any teaming activity, domestic or foreign, it is these types of communications issues that are most important and require early and consistent management attention.

It is also important to understand and respect the motivations of each team member to enter into the partnership. It is not uncommon that the reasons (i.e. value creation) for entering the teaming relationship are different for each of the team members.

Assured Access to Space

Historically, space launch vehicle programs in the first space-faring nations, the USSR and US, were strictly national programs, assuring independent and assured access to space as a matter of national security and demonstration of technological leadership. The first space launch

vehicles were derived from Intercontinental Ballistic Missiles (ICBM's), and the complete development, production and operation of the launch vehicle was tightly controlled by the respective government agencies and the military. International cooperation was neither needed nor desired. Other space-faring nations such as Japan, India and China also opted for national programs while Europe embarked on inter-European international cooperation to gain European independent access to space. Under ESA (European Space Agency) direction, the Ariane family of launch vehicles was developed and put into operation, utilizing funding and industry participation from various European countries. This type of cooperation has been very successful in the case of the Ariane 4 program, which matured into the world's most successful commercial launch vehicle in the 1990's.

It was this contentious and competitive nationalistic beginning of the space program that has set today's tone of hesitancy with respect to international cooperation in space launch activities. It is important to note, however, that there are significant differences between independent-access and assured-access to space. Considering that every major launch vehicle in the US has components produced in foreign countries, it is clear that the requirement for independent access is no longer required, if strong stable foreign relationships and agreements are achieved to enable an assured supply. Should independent access be required, it can in many cases be achieved by setting up co-production capability, which, however, may decrease the overall value by requiring additional investments.

As a result of the continued international competitiveness in the arena, there is an ongoing resistance within the US to allow technology to be transferred to other countries, regardless of the relationship. And although many of the reasons for these nationalistic postures are now softening, one key issue remains, the issue of proliferation. There are many countries in the world that do not have intercontinental ballistic missile capability, which is akin to space launch capability. As this is a capability that can directly threaten global security, it is the position of most countries that it should be limited to only the most responsible, stable and transparent governments. For international teaming to be successful and acceptable for licensing, all

parties must fully respect this fundamental philosophy to limit proliferation.

Government Licensing

International teaming for space launch propulsion requires the import and export of data, hardware and technology. For the US and 32 other countries the export of "missile" systems, subsystems and related technology are restricted and governed by the "Missile Technology Control Regime" (MTCR). The MTCR is neither a treaty nor an international agreement but is a voluntary arrangement among countries, which share a common interest in arresting missile proliferation. The Regime consists of common export policy applied to a common list of controlled items. Each member implements its commitments in the context of its own national export laws (ref. 1).

The annex of controlled equipment and technology is divided into "Category I" and "Category II" items. It includes equipment and technology, both military and dual-use, that are relevant to missile development, production, and operation. Category I includes complete rocket systems and certain complete subsystems such as rocket engines. According to the guidelines, export of Category I items is subject to a strong presumption of denial. Category II items include propulsion and propellant components, launch and ground support equipment, various other missile related components, and related technology, as well as certain other missile systems. Export of Category II items are to be subject to case-by-case review against specified nonproliferation factors. Needless to say, that the hurdles for obtaining export licenses for rocket engines are high. The MTCR Guidelines specifically state, however, that the Regime is "not designed to impede national space programs or international cooperation in such programs as long as such programs could not contribute to delivery systems for weapons of mass destruction" (ref. 1).

The MTCR is the cornerstone of US missile nonproliferation policy. For all practical purposes, US Government (USG) licensing for space launch propulsion is regulated by the "International Traffic in Arms Regulations" (ITAR), see ref. 2. As previously described, the

main objective of licensing is to control the transfer of space launch technology, especially as it applies to the issue of extending other countries capabilities and to the issue of proliferation.

US license types are primarily Technology Assistance Agreements (TAA's) and Manufacturing License Agreements (MLA's). Generally it is the provisos (special notes) of the licenses that can be the most important and controlling features for these documents. For teaming arrangements that are above a certain dollar threshold, currently \$50M, congressional notification is required. Finally, it is important to consider that all employees working on the program must be trained and certified concerning all aspects of the approved documents and their ITAR responsibilities. For everyday administration of license procedures within an international program, one of the most important documents supporting these licenses is the Technology Transfer Control Plan (TTCP) which must be in place and must be complied with by the US teaming partner at all times.

Some important features of USG licensing are summarized below:

- International Space Propulsion Programs are controlled by International Traffic in Arms Regulations (ITAR) as "Military and Space Launch Vehicle Power Plants" - and deemed "significant military equipment"
- ITAR "rules" are specified in 22 CFR 120-130 (Code of Federal Regulations)
- ITAR Data is any information needed for "... design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of defense articles."
- Full Compliance with ITAR is required; there are Severe Employee / Corporate Penalties for Violations
- USG Export Licenses are required for conducting International Space Launch Business (TAA, MLA, others)
- Licensing Agency is the Office of Defense Trade Control (ODTC) within the Department of State (DoS)
- TAA, MLA Licenses
 - contain specific Statements of Work for a Program between US and Foreign Company

- must be signed by both US and Foreign Company
- take time to be issued (~6 months)
- require a Technology Transfer Control Plan (TTCP) to be approved by USG before License Activation
- Monitoring of License and TTCP Rules by Defense Technology Security Administration (DTSA) (includes data approval, monitoring, records auditing)

It should be noted that information concerning general scientific, mathematical or engineering principles, basic marketing information or information in the public domain are not considered ITAR data. Public domain information can be characterized as published information which is generally accessible and available to the public, e.g. through libraries, universities, patent offices, bookstores, and publicly released documents such as papers at technical conferences, etc. However, any specific technical requirements and specifications needed by a foreign partner to respond, e.g., to a request for proposal by a US company is technical data under ITAR, and therefore appropriate licenses are needed at the very early stages of an international teaming effort.

Obtaining USG licenses is often envisioned as an insurmountable obstacle to international teaming. Unfortunately, for smaller companies this may be true due to the lack of knowledge, experience and manpower to tackle a complicated and often arduous process. For larger companies and corporations, with trained staffs and experienced with the restriction of ITAR this license acquisition and management process is more familiar and addressable.

Potential foreign partners will also need licensing agreements that must be obtained from their own respective governments. For example the license process in Russia seems to be similar to the US. However, for western European countries and Japan the license activities seem to be less arduous and restrictive.

Examples of International Teaming

In the following, three cases of major international cooperation in space launch propulsion will be discussed, starting with the successful Ariane propulsion programs in

Europe, followed by summaries of the RD-180 booster engine program and the SPW2000/RL60 upper stage engine programs, which represent major cooperation programs with US participation. Finally, international cooperation aspects of the JSF program will be highlighted, which could make it a role model for future international cooperation in space launch propulsion. For the purpose of this paper, a major cooperation in propulsion is characterized by industry teaming arrangements which involve the design, development and production of propulsion systems.

In the jet engine world there are many successful examples of major international teaming, such as the CFM56 and V2500 commercial jet engine programs, and more recently the JSF military engine program. A military program such as JSF is regulated by ITAR, but extra scrutiny is applied for space launch cooperation programs as they also fall under the Missile Technology Control Regime.

As noted earlier, there are some successful cases of international space launch propulsion cooperation with flight production hardware involving the US, see also ref. 3. For example, Snecma is providing large carbon/carbon nozzles for the RL10B-2 engine used on the Delta 4 vehicle, and Aerojet has been working with ND Kusnetsov to adapt their NK-33 engine for the Kistler reusable launch vehicle. The RD-180 engine being produced in Russia and currently in production and use for the Atlas III/V launch vehicles is the only successful example of a major international teaming effort in the space launch propulsion arena. The SPW2000 program by P&W and Snecma/ESA a few years ago came close to providing an advanced upper stage engine for both US and European launch vehicles, but that effort unfortunately was unsuccessful. Its history, as well as reasons for undertaking the effort and reasons for its eventual failure are also discussed below.

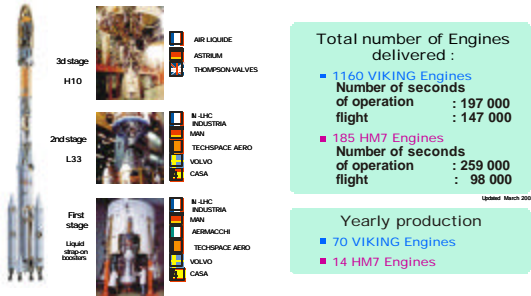
Ariane Propulsion Programs in Europe

At the European Space Conference in 1973, Europe took the decision to develop their own launch vehicle (Ariane), after years of unsuccessful efforts with the Europa launcher program. In 1974, the European Space Research Organization (ESRO) delegated the global management responsibility for launcher

development to the French Space Agency CNES, and in 1980 Arianespace was created as the world's first space transportation marketing company (ref. 4). Table 1 summarizes the history of European Cooperation before the Ariane program and highlights the European cooperation for Ariane launch vehicles. Fig. 1 shows the European industrial organization for the Ariane 4 program, with Snecma of France as the prime contractor for propulsion. Fig. 2 shows Snecma's responsibility for the Ariane 5 booster engine development and illustrates the many European team members contributing to this effort. Figure 3 shows the Vulcain 1 and 2 engines during a hot firing, and an Ariane 5 with the Vulcain booster engine in flight.

Table 1: European Cooperation (from ref. 4)

European Cooperation before Ariane																							
-	ELDO/ESRO Organization in the 1960s																						
-	Europa I and II Launchers																						
-	Cryorocket Company (50/50 Joint Venture between MBB of Germany and SEP of France)																						
-	Europa III Project																						
-	European Space Conference in Brussels, July 1973: Decision to start 3 Programs:																						
-	L3S Launcher(Ariane) led by CNES(France)																						
-	Spacelab(Coop with NASA) led by Germany																						
-	Maritime Satellite MAROTS led by UK																						
European Cooperation for Ariane Launch Vehicles																							
<u>Ariane 1 Organization:</u>																							
-	Development Program cost estimated in 1973: 2060 MF + 20% margin																						
-	Decision by ESRO in 1974 to delegate global management responsibility to the French Space Agency CNES, making CNES the Prime Contractor for Development																						
-	Financing:																						
	<table border="1"> <thead> <tr> <th>Participating Country</th> <th>% Contribution</th> </tr> </thead> <tbody> <tr> <td>France</td> <td>62.50</td> </tr> <tr> <td>Germany</td> <td>20.12</td> </tr> <tr> <td>Belgium</td> <td>5.00</td> </tr> <tr> <td>UK</td> <td>2.47</td> </tr> <tr> <td>The Netherlands</td> <td>2.00</td> </tr> <tr> <td>Spain</td> <td>2.00</td> </tr> <tr> <td>Italy</td> <td>1.74</td> </tr> <tr> <td>Switzerland</td> <td>1.20</td> </tr> <tr> <td>Sweden</td> <td>1.10</td> </tr> <tr> <td>Denmark</td> <td>0.50</td> </tr> </tbody> </table>	Participating Country	% Contribution	France	62.50	Germany	20.12	Belgium	5.00	UK	2.47	The Netherlands	2.00	Spain	2.00	Italy	1.74	Switzerland	1.20	Sweden	1.10	Denmark	0.50
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Spain	2.00																						
Italy	1.74																						
Switzerland	1.20																						
Sweden	1.10																						
Denmark	0.50																						
<u>Ariane 4 Production:</u>																							
-	Creation of Arianespace in 1980: first company worldwide responsible for operations relating to Space Transportation in general and for all industrial and commercial operations relating to Production / Marketing / Launch																						



Snecma is the Prime Contractor for Ariane 4 Propulsion

Figure 1: Ariane 4 Industrial Organization
(Courtesy of Snecma)

Snecma is the Ariane 5 Engine Prime Contractor

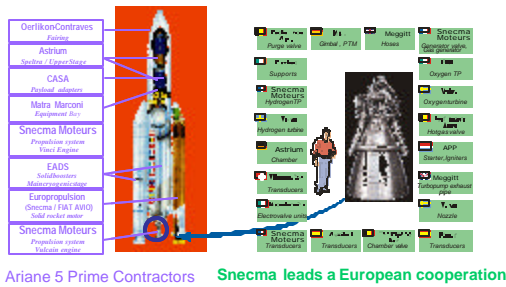


Figure 2: Ariane 5 Booster Engine Cooperation
(Courtesy of Snecma)

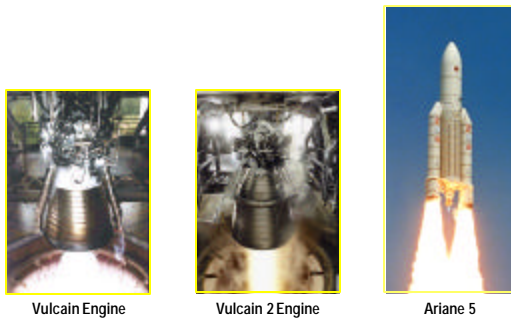


Figure 3: Ariane 5 Booster Engines Vulcain 1 and Vulcain 2
(Courtesy of Snecma)

The European cooperation in large liquid propulsion was clearly motivated by a strategy of European independent access to space. The Ariane program cooperation has been built over three decades, and over time more and more countries and companies have participated. One of the major features of this cooperation is the concept of “Geographical Return” which

requires the prime contractor CNES to place development contracts throughout Europe based on the percentage contribution of the participating countries. The cooperation has over the years resulted in the creation of “centers of excellence” which are distributed throughout Europe and have seen substantial investments by individual countries and companies to maintain their individual leadership roles in certain technologies and capabilities.

The success factors for this European cooperation in large liquid propulsion were summarized in ref. 4 as follows:

- Political Support
- Strong Organization of Management
 - Clear Requirements/ Specifications with Involvement of Industry
 - “Reasonable” Technical Choices based on Preparatory Phases (e.g. HM4, M40, P111)
 - Standardized Management Procedures, including Quality
 - Cost Control and Design-to-Cost Approach
- Realistic Budget Requirement Approach
- Commitment of Industry both in Development and in Production (as Shareholders of Arianespace)

The European cooperation has been very successful in the case of the Ariane 4 and 5 launch vehicle programs, with the Ariane 4 having matured into the world’s most successful commercial launch vehicle in the 1990s.

RD-180 Booster Engine Program

While there has been some limited international cooperation involving the US and companies in Europe, and between the USSR/CIS and other countries (Europe, India) in the past, a large scale transatlantic cooperation in space launch propulsion did not materialize until the mid-1990’s, with the Russian RD-180 engine eventually powering the boost stage of the Atlas III/V launch vehicles. The RD-180 engine was derived from an existing engine, the RD-170, and Pratt & Whitney in the US provided the development funding, systems engineering and product integration, while NPO Energomash of Russia was responsible for hardware design,

manufacturing and testing, as well as engine production and acceptance testing.

The following provides a list of the main reasons for Pratt & Whitney and NPO Energomash to enter into the RD-180 partnership (ref. 5):

- International teams bring strengths from both partners - broad international experience base
- International teams bring funding and other resources from both partners
- International market opens additional opportunities for product evolution (RD-170, RD-180, RD-191)
- Resultant evolved products allow reduced development costs and schedule
- Derivative engine models with mature design and technology enable increased reliability
- Through a JMTLA (Joint Marketing Technology License Agreement), Pratt & Whitney has the ability and the rights to
 - utilize Russian (Energomash) technology
 - provide proven RD-170 flexibility, reusable and man-rated technology
 - support new markets and provide competition for U.S. opportunities

This Russian-American cooperation to rapidly develop, certify and field the RD-180 booster engine is unprecedented. The program history can be summarized as follows:

- RD-180 booster engine was originally pursued by General Dynamics in early 1990's for a proposed Atlas upgrade.
- General Dynamics merged with Martin Marietta, and later became Lockheed Martin in 1995. Competitions held to upgrade Atlas booster propulsion.
- In 1995, Lockheed Martin selected the team of NPO Energomash and Pratt & Whitney to develop the RD-180 for the Atlas IIAR (now Atlas III) and eventually for the EELV Atlas V (to address both commercial and U.S. Government requirements).
- In early 1997, RD AMROSS was formed to formally establish production and sell flight engines/launch services to Lockheed Martin.

- A three-phased development and certification program is now complete which certified the RD-180 for use on the Atlas III and Atlas V.

Figure 4 shows a timeline of RD-180 program key events. It took less than five years from program start to the first flight of the Atlas III. Fig. 5 shows pictures from this first flight, which was launched at Cape Canaveral Air Force Station on 24 May 2000.

The RD-180 engine enables Atlas launch vehicle growth by providing a cost-effective engine with the following unique features, which enhance the launch vehicle effectiveness:

- Smooth and continuous throttling from 47% power to 100% power
- Atlas V booster engine interchangeability with Atlas III
- Self-contained engine pneumatic system, 4 fewer fluid interfaces than with previous engine
- Self-contained thrust vector control actuators; no auxiliary roll system required
- Self-contained hydraulics after engine start
- Reduced engine integration and checkout time, 12 days vs. 80 for previous engine
- Possibility to use single engine in 2nd stage
- Reduced engine cost

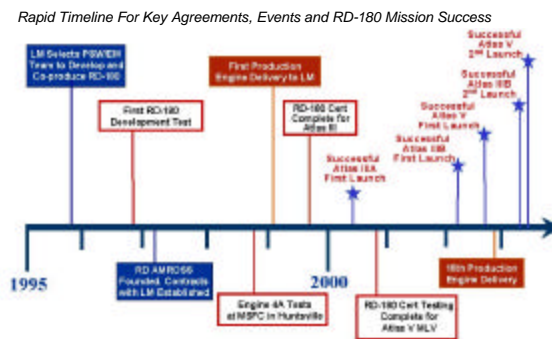


Figure 4: Timeline of RD-180 Key Events

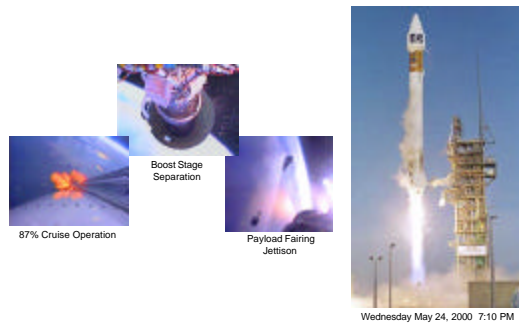


Figure 5: First RD-180 Flight, on Atlas IIIA, May 24, 2000

Figure 6 shows the Lockheed Martin Atlas launch vehicle family and the GTO payload capabilities for the different Atlas III and Atlas V versions with RD-180.

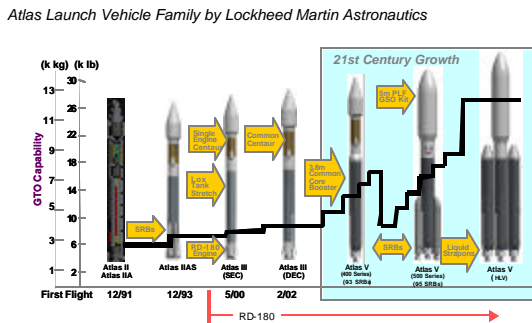


Figure 6: Atlas Launch Vehicle Family by Lockheed Martin Astronautics

The RD-180 engine was derived from the NPO EM designed man-rated and reusable RD-170 engine. RD-170 component designs accumulated more than 900 tests and 100,000 seconds of test time. The RD-180 engine has 70% common hardware with the RD-170, and 30% of the hardware is scaled from RD-170. Its oxidizer rich staged combustion cycle and high chamber pressure provide the highest performance of any operational LOX/kerosene engine worldwide. Figure 7 shows this RD-180 heritage; Figure 8 shows an RD-180 engine test at NASA's Marshall Space Flight Center. Further information on the RD-180 program may be found in ref. 6.

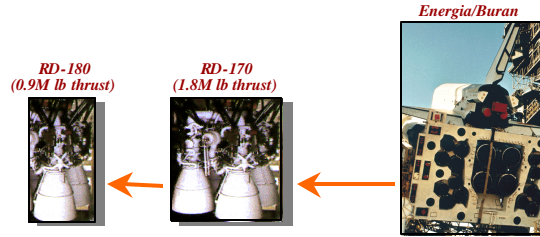


Figure 7: RD-180 Heritage

The RD-180 engine is currently in serial production, with 16 engines delivered and 5 of those flown. It is built in Russia, flown to Lockheed Martin in Denver for vehicle integration, and is launched from Cape Canaveral. Fig. 9 shows pictures of engine delivery, receiving inspection and engine-to-vehicle integration.

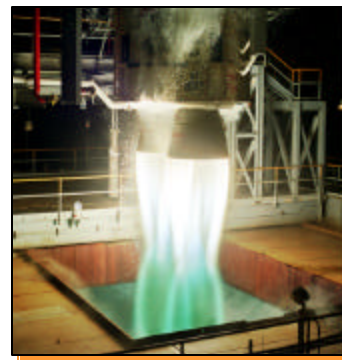


Figure 8: RD-180 Engine Test at NASA's Marshall Space Flight Center

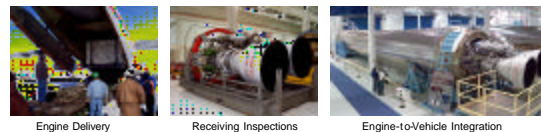


Figure 9: RD-180 Engine Delivery

Marketing, sale, shipment and support services for the RD-180 and derivative engines are handled by RD AMROSS, a 50/50 Pratt & Whitney / NPO Energomash Joint Venture company incorporated in the US. This was made possible by a Russian Presidential Decree issued in 1996 supporting the joint venture. The company was subsequently incorporated and registered in Delaware in January 1997. It is operated as an independent company with a

board of directors, President and CEO, secretary, treasurer and deputy treasurer. A master support and license agreement assigns all RD-180 rights from P&W and NPO EM to RD AMROSS and allows it to manufacture engines in Russia and the U.S., certify them for flight, sell them, provide integration and flight support services, and use unique designs, patents and technologies for RD-180 derivative products under new licenses.

Figure 10 provides an overview of the RD AMROSS joint venture and the responsibilities of its two partners, and Figure 11 outlines the various contractual relationships used for conducting business.

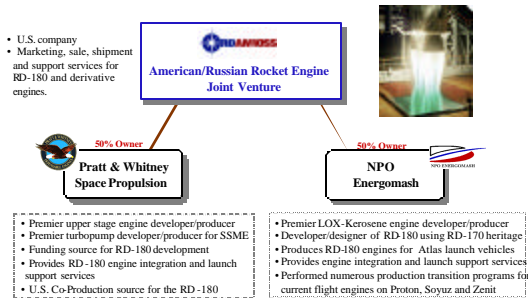


Figure 10: RD AMROSS Joint Venture

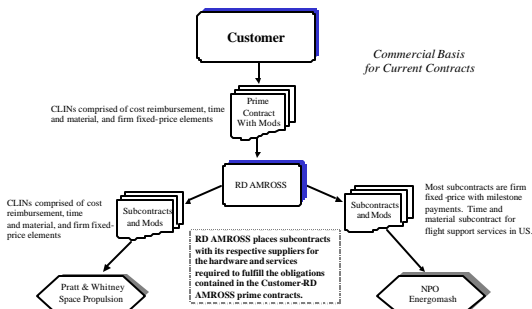


Figure 11: RD AMROSS Contractual Relationships

The Russian-American cooperation in the RD-180 program is unprecedented, very unique, and represents a very successful example of a major cooperation in the space launch propulsion industry. The technical, political and programmatic challenges leading to this success were overcome by unprecedented levels of cooperation and trust at all levels between governments, companies and individuals.

SPW2000 and RL60 Upper Stage Engine Programs

In 1999, Pratt & Whitney in the US had started the development of a new, advanced cryogenic upper stage engine, the RL50, as a commercial, self-funded venture based of the perceived future market needs as envisaged at that time. A higher thrust, high performance upper stage engine would be needed for the next upgrade cycles of the US launch vehicles Delta IV and Atlas V. In Europe, Snecma of France had started the development of a new advanced upper stage engine, VINCI, under an ESA-funded program to upgrade the Ariane 5 vehicle with a high performance cryogenic upper stage, ESC-B. During the latter half of 1999 and early 2000, Pratt & Whitney and Snecma, with the support of CNES, established a plan to jointly develop a new cryogenic upper stage engine which encompassed the requirements and capabilities of both the RL50 and the Vinci engines. It was thought that effective cost management and economies of scale could be achieved by developing one engine to meet the future needs of both US and European expendable launch vehicles. The engine was given the designation SPW2000, signifying the partnership (Snecma/Pratt & Whitney) and the new millennium. CNES authorized a system concept study which was officially kicked off in December 1999 and led to a successful engine systems definition, which was accepted by CNES in a formal review (with all the required extensive program and technical documentation) six months later.

Unfortunately, the program was not fully embraced by ESA, and the ESA council decided to discontinue the program in June of 2000. ESA resumed the VINCI engine program in its original all-European version, and Pratt & Whitney in turn decided to pursue its own engine program, the RL60, starting with a three-year demonstrator engine development phase. Based on SPW2000 experience and efforts, Pratt & Whitney decided to retain some of the European content as well as incorporating contributions from Russia and Japan. The following provides a summary of the international aspects of the SPW2000 and the RL60 programs.

The main reasons for undertaking the international teaming effort on SPW2000 can be summarized as follows:

- Timing seemed right: Separate development programs with similar requirements had just been started independently by two engine primes. The SPW2000 engine family would fulfill the requirements of both Pratt & Whitney's and Snecma's launch vehicle customers, see Fig. 12
- Less program investment required for each partner individually
- Lower per-unit recurring cost due to higher production rates
- The new engine would mature faster due to faster acquisition of operational data
- Reduced development risk due to redundant capabilities in some areas (e.g. engine test stands)

A joint program office was established by Pratt & Whitney and Snecma to manage the SPW2000 program, see Fig. 13. Each partner was to maintain its own interface and responsibility with his respective customers.

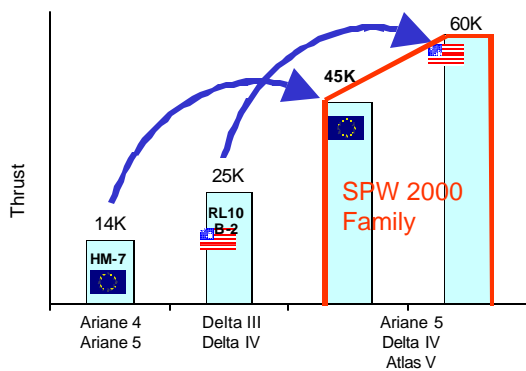


Figure 12: SPW2000 Engine Applications

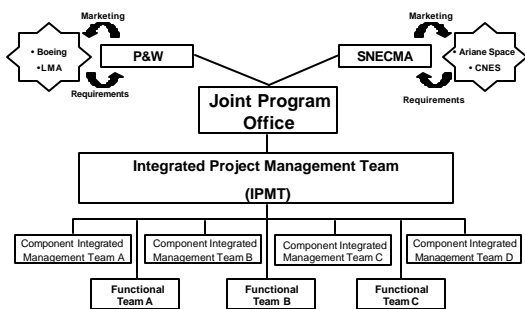


Figure 13: SPW2000 Joint Program Organization

System design activities were to be shared between the partners, and both companies were responsible for assigned engine component designs. System integration, development testing and certification activities were again to be shared, based on pre-assigned tasks. During the production phase, each company would set up its own final assembly and test and maintain its respective customer interfaces. Figure 14 summarizes this plan of joint engine development and production flow.

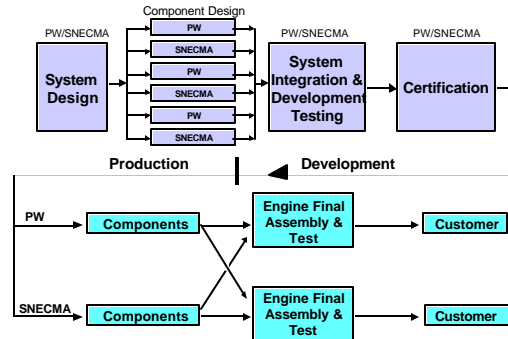


Figure 14: SPW2000 Joint Engine Development and Production Flow

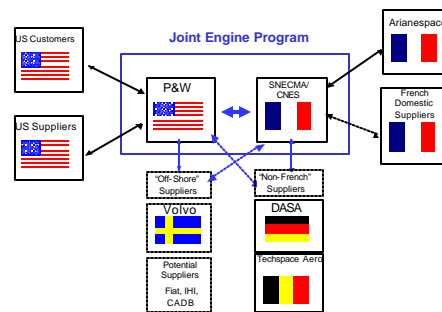


Figure 15: SPW2000 Program Working Relationships

The overall development and production effort would involve many different individual companies in different countries (see Fig. 15), which required appropriate contractual arrangements and licenses. Following USG requirements, Pratt & Whitney and Snecma needed a Manufacturing License Agreement (MLA) authorizing joint development and production between Pratt & Whitney (US) and Snecma (France) with various European subcontractors. Obtaining this license was a fairly involved and complex process. The

following describes the milestones of this process:

- First Presentation of Joint Program to DoS: January 2000
- MLA Submittal: mid-March
- ODTC Advisory Opinion Provisos Issued: end of March
- MLA staffed for Interagency Technical and Policy Review: early April
 - DoD: DTRA, USAF, Counterproliferation
 - DoS: Export Control & Conventional Arms Nonproliferation, Office of Chemical/Biological/Missile Nonproliferation, Missile Technology Export Control Group (MTEC)
 - NASA
- USG Agency Reviews concluded: early June
- Congressional Notification: mid-June
- License Issued: early July

The license was issued within six months and allowed the SPW2000 program to go forward as planned. Unfortunately, as mentioned above, ESA decided against the continuation of the program, even though the program had passed the formal CNES system concept review and the USG export license had been granted.

What were the reasons why the SPW2000 effort was not successful? The main reasons can be described as follows:

- Industrial base issues. The “geographic return” would have changed and some European companies would not have had the same work share as in the VINCI program
- European concern over USG policies which could have led to future export license restrictions (“Assured Access”)
- Lack of understanding of USG licensing process by some European parties
- Timing was not right after all. The ESA plan for VINCI was already well established (with traditional individual European contributions and returns) when the SPW2000 effort was started

After the cancellation of the SPW2000 program, Pratt & Whitney decided to pursue its own engine program, the RL60, starting with a three-year demonstrator engine development phase. This program allows Pratt & Whitney to mature and demonstrate enabling technologies of this new high performance expander cycle engine while maintaining a strategic position for future full-scale engine development. Fig. 16 shows a summary of cryogenic upper stage engines, both existing engines and engines under development.

The RL60 design point is at 60 k-lbf, and the engine can safely operate in the thrust range from 40 to 65 k-lbf. Figure 17 provides the RL60 engine program schedule. The RL60 engine design is defined and demonstrator engine testing will take place in 2003.

The RL60 Has Over Twice the Thrust as RL10B-2 in the Same Envelope

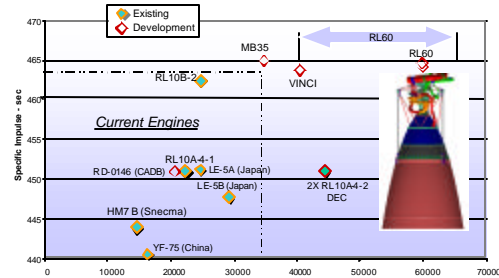


Figure 16: Summary of Cryogenic Upper Stage Engines with RL60

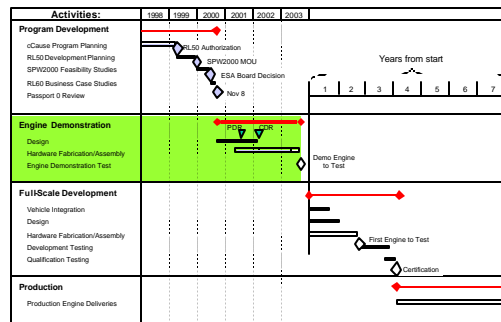


Figure 17: RL60 Engine Program Schedule

The demonstrator phase is fully funded by Pratt & Whitney and some of its international partners who are making significant investments in this program. Figure 18 provides an overview of the engine and the responsibilities for its major components. Techspace Aero and Volvo were partners on the SPW2000 engine and were invited to continue their cooperation for the RL60 program. In addition, CADB of Russia and IHI of Japan provide major components. These international partnerships are well established and allow a competitive engine development and production. In addition, Pratt & Whitney can also fully support any potential future US domestic RL60 programs, due to the fact that it either owns the design rights or has appropriate contracts in place allowing for US license production.

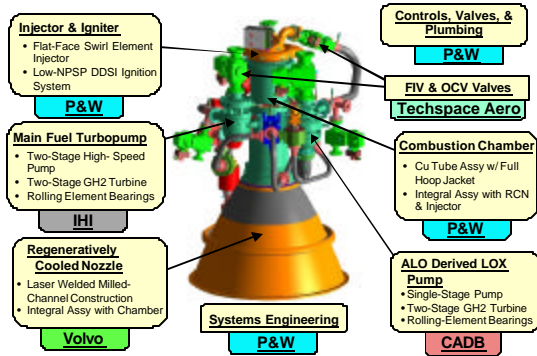


Figure 18: RL60 Demonstrator Engine Overview with International Partners for Major Components

Finally, it is worth pointing out some differences between the international aspects and the level of involvement and complexity between the RL60 and the SPW2000 programs:

RL60 Program:

- One Engine Prime: Pratt & Whitney
- International and US Domestic Subcontractors
- Pratt & Whitney and Partner Funding only; no Government Funding
- Single Partnerships result in relatively straight forward Contractual Arrangements and Export Licenses
- International Partnerships are well established

SPW2000 Program:

- Joint P&W / Snecma Program Office
- Joint P&W / Snecma System Design and Development
- Various Subcontractors in ESA Member States and in US
- Production: P&W Prime for US, Snecma Prime for Europe
- Snecma Development Funding by ESA, P&W Development self-funded
- Multiple Connected Partnerships require Complex Contractual Arrangements and Export Licenses

Joint Strike Fighter Program

The Joint Strike Fighter (JSF) is a successful example of a major international cooperation for

a military program which falls under ITAR, and thus bears significance as a potential role model for international cooperation in future space launch programs. The vision for the Joint Program Office (JPO) includes a direct reference to international cooperation and is stated as follows:

“Be the Model Acquisition Program for Joint Service and International Cooperation, Develop and Produce an Affordable Next Generation Strike Fighter Weapon System and Sustain it Worldwide”.

It specifically calls for international cooperation for development and production and looks for Best Value (“Affordable”). While JSF is accomplishing many technological firsts, perhaps the more important aspect is the programmatic firsts that may make the JSF program a model for future joint and multinational acquisitions. The program was structured from the beginning to be a model of acquisition reform, with an emphasis on jointness, affordability, an interchangeable engine, international participation, and “best value” acquisition (ref. 7).

Reasons for international participation are as follows:

- Conceived as an International Acquisition Program in order to attract Financial Investment and Technological Innovation from Partner Countries (“Best Value” Approach)
- Partner early with Governments whose Military Services are likely Users of this State-of-the-Art Coalition Forces Platform
- Improved Coalition Warfare: Multinational War Fighters use the Same Platform, Tactics and Operational Concepts
- Good Business Case for Foreign Partners
- Large Production Base
- Potential for Long-Term Relationships, Single Source Procurement

Early lessons learned in JSF may help programs such as Missile Defense, Future Combat System, Littoral Combat Ship, Multi-Mission Maritime Aircraft, Deepwater optimize their own international acquisition strategies.

Fig. 19 shows a representation of the JSF international strategy and cooperative framework, with features as also seen and discussed above in the space propulsion cooperation cases. The US is partnering with eight countries for the System Design and Development Phase (SDD), with international representation in the JPO. These countries collectively have invested about \$4.5B, which represents about 18% of total SDD funding.

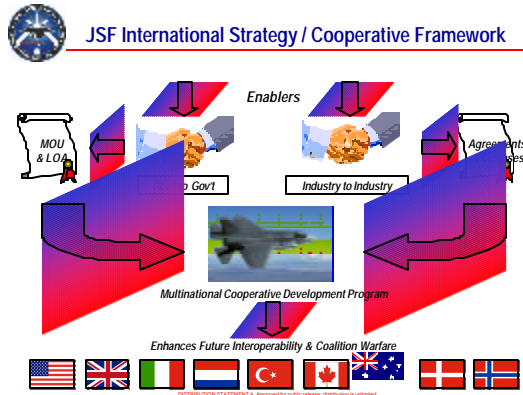


Figure 19: Joint Strike Fighter International Strategy and Cooperative Framework

Two engine sources are being developed and will compete in the production phase. The Pratt & Whitney and General Electric engines will be physically and functionally interchangeable in order to minimize development and support costs. Fig. 20 shows the Pratt & Whitney F135 propulsion system approach, and Fig. 21 shows a development engine in operation during a X-35 test flight. Pratt & Whitney is the propulsion system prime contractor, with team members Rolls-Royce and Hamilton Sundstrand. This propulsion system team is working with industries in all eight partner countries, with all of those countries offering best value in terms of technology and affordability to the JSF program.

The JSF program and its new program approach has been very successful, even though it had to deal with the typical issues in international cooperation, e.g. conflicting industrial interests (here: Eurofighter participation instead of JSF participation). Also, export control issues have plagued virtually all of the JSF international partners. In summary, though, the new international approach fully embraced by the JSF

program, is very successful and could provide valuable lessons learned for future international space launch propulsion programs.

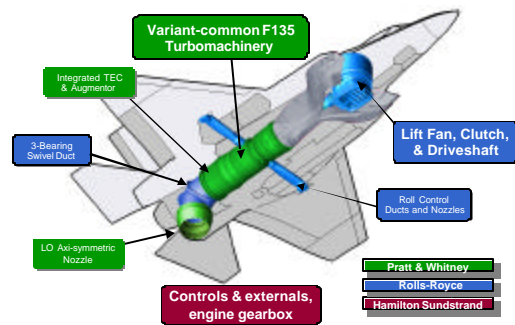


Figure 20: Pratt & Whitney F135 Propulsion System Approach



Figure 21: X-35 Test Flight with Pratt & Whitney F135 Development Engine

Lessons Learned

There are many lessons which can be learned from above examples of international cooperation, and the experiences in other international teaming efforts are also similar (see e.g. ref. 3). The key issues which make an international effort in space launch propulsion successful, are always the same, with emphasis shifting depending on the specifics of the program and the partners and countries involved. The most important lessons learned can be summarized as follows:

- Mutual Cooperation must benefit all Parties (“Create Value”)
- Joint Programs need Long Term Vision
- Joint Programs need strong shared Will of Partners and Partner Country Agencies at High Levels

- Get all the Players involved early in Program Planning
- Consult all Regulatory Agencies early and brief the Scope to be pursued
- Need Clear Understanding by all Parties of Goals, Procedures, Roles and Responsibilities
- Personal Relationships are Key to Cooperation (“Trust”)

Concerning the three key factors introduced earlier, namely communications, assured access, and licensing, the following additional comments are offered:

Communications

Communications is the most important aspect of a successful teaming arrangement. Each partner must be fully aware and respect key motivational issues from their international partners’ perspectives. There must be a clear understanding of how the cooperation will be managed and the subtleties of the differing cultures that are inevitable. This is most important as the activity runs into unforeseen problems that must be mutually solved. There is a Russian proverb that paraphrased says “Partners can only trust each other after they have eaten a bag of salt together” meaning that it is the overcoming of a major problem together that ultimately builds true trust in the relationship.

Assured Access

Assured access will almost always be an issue, either by the US or by the partnering country, or by both. It is important to remember that assured access is different from independent access. Independent access may require co-production in one or both of the countries involved. As this will impact the economics of the partnership these issues should be worked out very early in the program.

Licensing

The key issue for a US partner is to start the licensing process early, to inform the State Department of the intentions of the teaming and to identify the resulting positive value to the US economy. In the case of government involvement, it is important to identify and explain the benefit of the partnership to these agencies and to solicit their support during the

licensing process. The same approach is probably true for any international partner in their respective country.

It is important to note that the license process can and should be used to help create benefit for the program. The detailed planning and discipline required for the licensing procedure serves to bring the needed management structure to the program, including a clear template for roles and responsibilities and program organization.

Summary and Conclusions

Space launch propulsion is part of a military heritage and national interest and security culture which presents very specific challenges to overcome. However, international cooperation can and will be successful, but only if all involved parties benefit from it. The creation of substantive value for each team member is a necessary condition for any such cooperation to be successful, as was illustrated in this paper. If this is not the case (e.g. SPW2000), the cooperation will fail. Import/Export issues are no show-stoppers, however, much work is needed to make sure each partner fully understands the license process and its implications. Assured access to space issues can be overcome. For a US based partner, however, it would be helpful if such international partnerships are more fully embraced by both NASA and the military, as is the case in the JSF program. For this type of international cooperation to occur for space launch propulsion, the timing must be right, the politics must be right, and the application must be right.

To date, the beginnings of cooperation in space launch propulsion have been limited in nature and commercially driven. The RD-180 program is the best example of a successful major international cooperation, with an engine produced in Russia and flown on a US launch vehicle. A truly joint propulsion system development program along the lines of a CFM56, V2500 or JSF type cooperation in the jet engine world has not yet been undertaken, although the SPW2000 program by Pratt & Whitney and SNECMA/ESA a few years ago came close. A commercial partnership can be successful if the international team has a competitive capability, which is not found in the individual team members alone (complementary capabilities). Another strong driver is economies

of scale, i.e. an increased production base as a direct result of the product application. The SPW2000 approach with one engine for three different launch vehicles is a good example. If the product is used in applications in different countries, it is at least beneficial, but more likely necessary, that the customer interfaces are handled by the partner residing in his respective customer's home country. In addition, any emerging opportunity for a new product must be well prepared to be able to seize upon it, as these opportunities do not occur very often due to the long product life cycles (typically 10 - 40 years).

The other possible scenario for a major international cooperation involving space launch propulsion would arise if an ISS-type arrangement for a space launch vehicle or space transportation vehicle were created. Introducing such a large scale international cooperation can also have a stabilizing effect on the program. Potential applications that are 'prime' for international cooperation for propulsion include new reusable launch vehicles and systems for the exploration of the moon and Mars. Both applications are aggressive, expensive and worthy of global participation. Cooperation in these areas would serve to reduce overall risk and increase value by bringing together complementary skills and technologies, reducing the investments required by participating countries, provide a global focus for the space launch industry and introduce multiple unforeseen opportunities for commercial economic expansion. The concepts to be pursued would still be subject to licensing restrictions, but the focus of these activities would be less threatening in nature relative to issues of proliferation.

References

1. Missile Technology Control Regime Website: www.mtcr.info/english, July 2003.
2. International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120-130, U.S. Government Printing Office, Revised as of April 1, 2003.
3. "International Cooperation in Liquid Rocket Propulsion", various Invited Presentations and Panel Discussion, Session 106-LP-17, chaired by M. Popp and U. Palmnäs, 37th Joint Propulsion Conference, Salt Lake City, UT, July 2001.
4. "European Cooperation for Ariane Propulsion Systems", M. Pouliquen, Presentation during Invited Session on "International Cooperation in Liquid Rocket Propulsion", Session 106-LP-17, 37th Joint Propulsion Conference, Salt Lake City, UT, July 2001.
5. "International Liquid Rocket Cooperation - The Case of the RD-180 Engine", J.R. Bullock, 52nd International Astronautical Congress, Toulouse, France, October 2001.
6. "Atlas with RD-180 Now", Katorgin, B.I., Chvanov, V.K., Chelkis, F.Y., Ford, R.N., Tanner, L.G., AIAA-2001-3961, 37th Joint Propulsion Conference, Salt Lake City, UT, July 2001.
7. "JSF International Industrial Participation: A Study of Country Approaches and Financial Impacts on Foreign Suppliers", Department of Defense, June 2003.