CHEMICAL PROPULSION TECHNOLOGY

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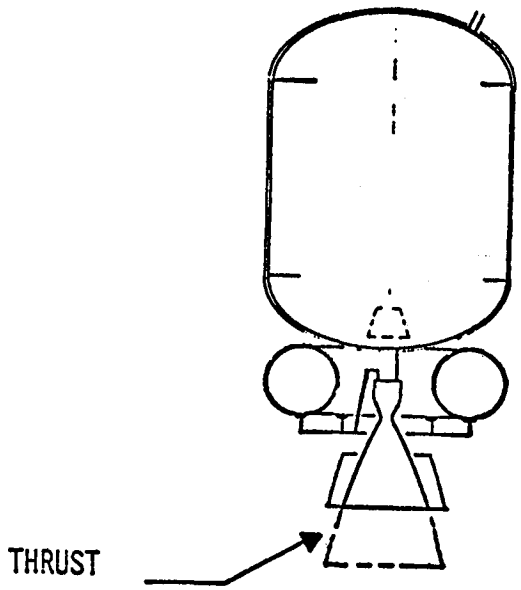
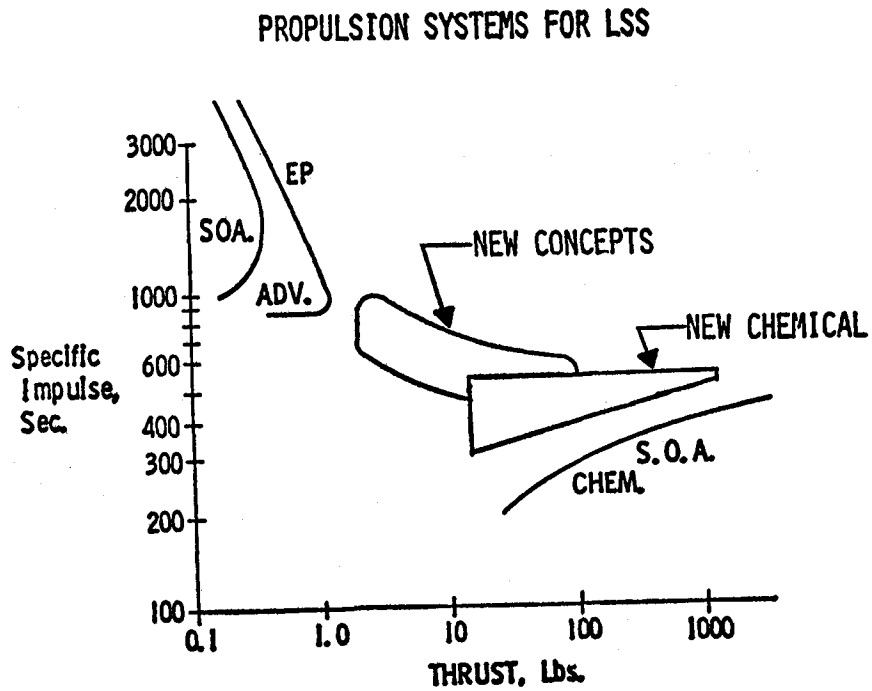
NASA's Low Thrust Liquid Chemical Propulsion Program is represented in the following charts. They have been used in presentations to several of the NASA Overview Committees in the past couple of months and are in a program plan that contains most of this information, so they represent an overall view of the chemical propulsion technology program. This presentation pertains to thrust system technology in the ten to thousand lb. thrust range. This chart schematically shows the elements of the propulsion system, with tanks, structures, and engines included in the program.

LOW THRUST CHEMICAL PROPULSION TECHNOLOGY PROGRAM



This chart shows that the new chemical program that we are talking about is in the ten to thousand lb. thrust range and a specific impulse which is close to 500 sec. The state-of-the-art drops off very rapidly in the low thrust range. This is why we are speaking of a dedicated thrust system in the low thrust range. There are other programs in the thousand lbs. and higher thrust range that are used for orbital transfer. I am not discussing that today.



The objective of the program, shown in this chart, is a technology program as Dick Carlisle mentioned before: We want to provide the tools, data, and analyses to allow propulsion system designers and people that do mission studies to optimize the actual system. We also need to develop new techniques that are required for this low thrust system, including throttling of the chambers, how to cool very small chambers, pumps and packaging of the complete system. The program also has to demonstrate the technology readiness, both in the components and possibly in the total propulsion system.

OBJECTIVES OF LTCP PROGRAM

TECHNOLOGY PROGRAM THAT:

- PROVIDES TOOLS (DATA, ANALYSIS, DESIGN PROCEDURES) TO DEFINE PROPULSION SYSTEM PERFORMANCE, WEIGHT, SIZE, ETC. IN TERMS OF ENGINE DESIGN VARIABLE (THRUST, PRESSURE, ETC.)
- DEVELOPS NEW TECHNIQUES NEEDED FOR LSS MISSIONS (THROTTLING, COOLING, PUMPS, PACKAGING, ETC.)
- DEMONSTRATES TECHNOLOGY READINESS (COMPONENTS AND PROPULSION SYSTEM)

The elements of the program are shown in this chart. The fundamental technologies are studies to establish what the engine requirements are. Cooling studies are listed, because cooling is a severe problem, especially at low thrust. We think that high pressure might be required, so we have included pumps, bearings, and seals. Also included are throttling concepts. In the components and engine systems area, we have to design and test these components to demonstrate that they are truly feasible and that the critical technology is available. We also need simulation tests of the engine systems for the most difficult technology. This is where we are not sure how far we have to go (how far we have to get into simulation testing as part of the program). The last step would be for a breadboard system to demonstrate that the complete technology is ready for a full system development. Again, we are not sure at this time whether a breadboard system would be required, but have included it in the program.

The key issue that we see in the low thrust chemical propulsion is high performance of cooled low thrust engines. You have already seen that we have achieved low performance, low I_{sp} down in these low thrust ranges. Now we must demonstrate high performance and long life, which requires cooling. We believe this will require small cryogenic pumps, and they are not available in the state-of-the-art. Multiple starts appears to be a requirement for perhaps ten starts and shutdowns, with a slow ramp such that the structure is not damaged by a sudden change in acceleration. Thrust variation could be 4 to 1 in flight so that constant g's are maintained as propellant is used up. For different missions, it is possible that a thrust range of 20 to 1 would be needed. Very long life is required. At very low thrust levels, a hundred hours of engine firing time is needed to complete a mission. We also have to improve the system weight and size. The final item is the selection of propellants, because defferent propellant systems have different characteristics that might be desirable for different missions. These are the key issues as we see them right now.

KEY TECHNOLOGY ISSUES FOR LOW THRUST CHEMICAL PROPULSION

- High Performance of Cooled - Low Thrust Engines
- Small Cryogenic Pumps
- Multiple Starts - Shutdowns (10) with Slow Ramps ($\lesssim$ 10 Seconds)
- Thrust Variation - 4/1 in Flight and 20/1 Between Flights
- Long Life (100 Hours)
- Improved System Weight and Size
- Propellant Selection

ELEMENTS OF LOW THRUST PROPULSION PROGRAM

- FUNDAMENTAL TECHNOLOGIES
  - Studies to Establish Engine Requirements
  - Cooling Studies & Tests
  - Pump, Bearings, Seals, Fabrication Studies
  - Throttling Concepts
- COMPONENTS & ENGINE SYSTEMS
  - Design & Testing of Components to Demonstrate Feasibility of Critical Technology
  - Simulation Tests of Engine Systems with Most Difficult Technology
- BREADBOARD SYSTEM TEST
  - Demonstration of Technology Readiness to Achieve Life, Performance, Throttling and Multiple Start

This chart includes funding level. This is from a planning document and therefore, it shows fiscal years from when we get the increased funds that are required to accomplish the program. The first year could be the fiscal 81 or 82 program. Currently we have payload/propulsion interactions studies going on. You will hear about these later. There are cooling concepts and pump analysis studies that are being conducted, and you will also here about these later.

The next phase of the program will consist of component design, fabrication and testing in the critical technology areas. This would lead to life and performance tests to demonstrate the technology. The final phase, which I am not sure will be required, would include a complete breadboard of the system. Breadboard means not necessarily lightweight, but creation of the conditions that are needed for an engine. This would demonstrate that the technology for a complete system is available. We definitely would carry it through the design phase of the program. The final phase consists of altitude testing, because of the very large expansion ratio nozzles which have not been demonstrated to date.

That summarizes the chemical propulsion program as we see it now. The funds shown are what we think are required to do the program. This funding level is in the FY82 budget. We are planning for it. On the other hand, it is roughly double or triple the funds we have available right now for the program.