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PROBE DESIGN AND SYSTEM INTEGRATION

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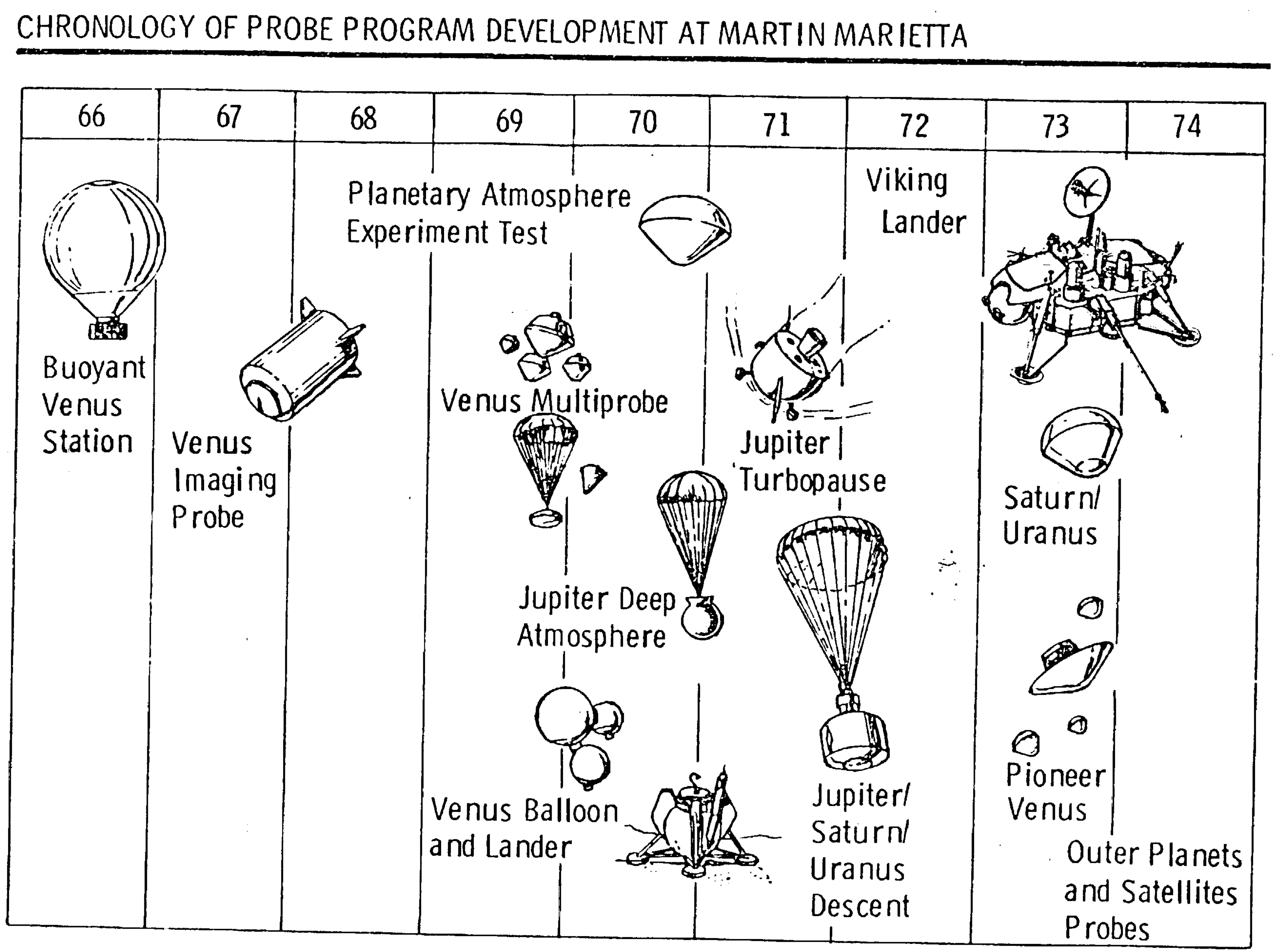
MR. CARROLL: I shall discuss a recent contract that Martin-Marietta has had to study the adaptability of existing hardware systems to a Pioneer Saturn/Uranus probe.

A previous speaker has charged the people who are designing for advanced probes to the outer planets, to start thinking about reduced cost. And part of the objective of this study under contract to Ames was to look at just that. What can we do in the way of using existing hardware to reduce program cost?

Figure 4-38 depicts past and current activities of Martin-Marietta and is representative of the type of activities that the whole industry under NASA and JPL sponsorship has been conducting through the last eight years or so.

The early efforts in 1967 and 1968 did bring up the point that it is very difficult to design an engineering system without established and consistent criteria from the scientists. And in those early days, scientists' opinions were varied. It was difficult to design an engineering system because of the large variation in criteria for design.

One of the first attempts, the Venus multiprobe study which was done for JPL, was a rather extensive trade study to assess the value of each of the science instruments and to determine the cost to implement them. As you can see, various approaches were taken. There were at that time both small and large probes. There were balloon systems as well as very high altitude probes designed to obtain data above the clouds.


CHRONOLOGY OF PROBE PROGRAM DEVELOPMENT AT MARTIN MARIETTA
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Buoyant Venus Station
Venus Imaging Probe
Planetary Atmosphere Experiment Test
Venus Multiprobe
Jupiter Deep Atmosphere
Venus Balloon and Lander
Jupiter Turbopause
Viking Lander
Jupiter/ Saturn/ Uranus Descent
Saturn/ Uranus
Pioneer Venus
Outer Planets and Satellites Probes

FIGURE 4-38

Those efforts led into the Jupiter deep atmosphere probe studies for JPL. These probe designs went down to 1000 atmospheres pressure; and at that time it was becoming obvious that the cost of descending to 1000 atmospheres pressure within the temperature environment was so great that the scientists then were willing to back off to what they then felt were adequate science criteria, somewhere around ten to thirty bars.

During that time, because of the difficulty and risk of heat shield development, Goddard came up with the concept of a Jupiter turbopause probe. It was a backup position in case it would be difficult or impossible within the budgets to develop heat shields for entry into Jupiter. There was a possibility that one could determine some of the basic science by just skimming into the upper atmosphere. That probe was not required to survive entry, however, the uncertainties in determining survival down to the turbopause where the composition could be measured were quite large. So that idea has been dropped from further consideration.

In addition, JPL looked at other approaches and finally these efforts did lead into Jupiter-Saturn-Uranus concepts of commonality. These efforts then led to the most recent Ames contracts to evaluate and design Saturn-Uranus probe systems.

Of course, Langley was active in much of this early work and the current Viking program, provides us with a comparison of the very sophisticated vehicle, with very sophisticated science, and high cost against our more cost constrained probe design. I think the trends we have talked about are leading to less costly systems with reasonable and adequate science.

Figure 4-39 depicts a configuration that resulted from our studies; although in detail the configuration is a little different from those of some of the other studies, in principle it is similar. We did look at all of the subsystems and assess the

SATURN/URANUS PROBE CONFIGURATION

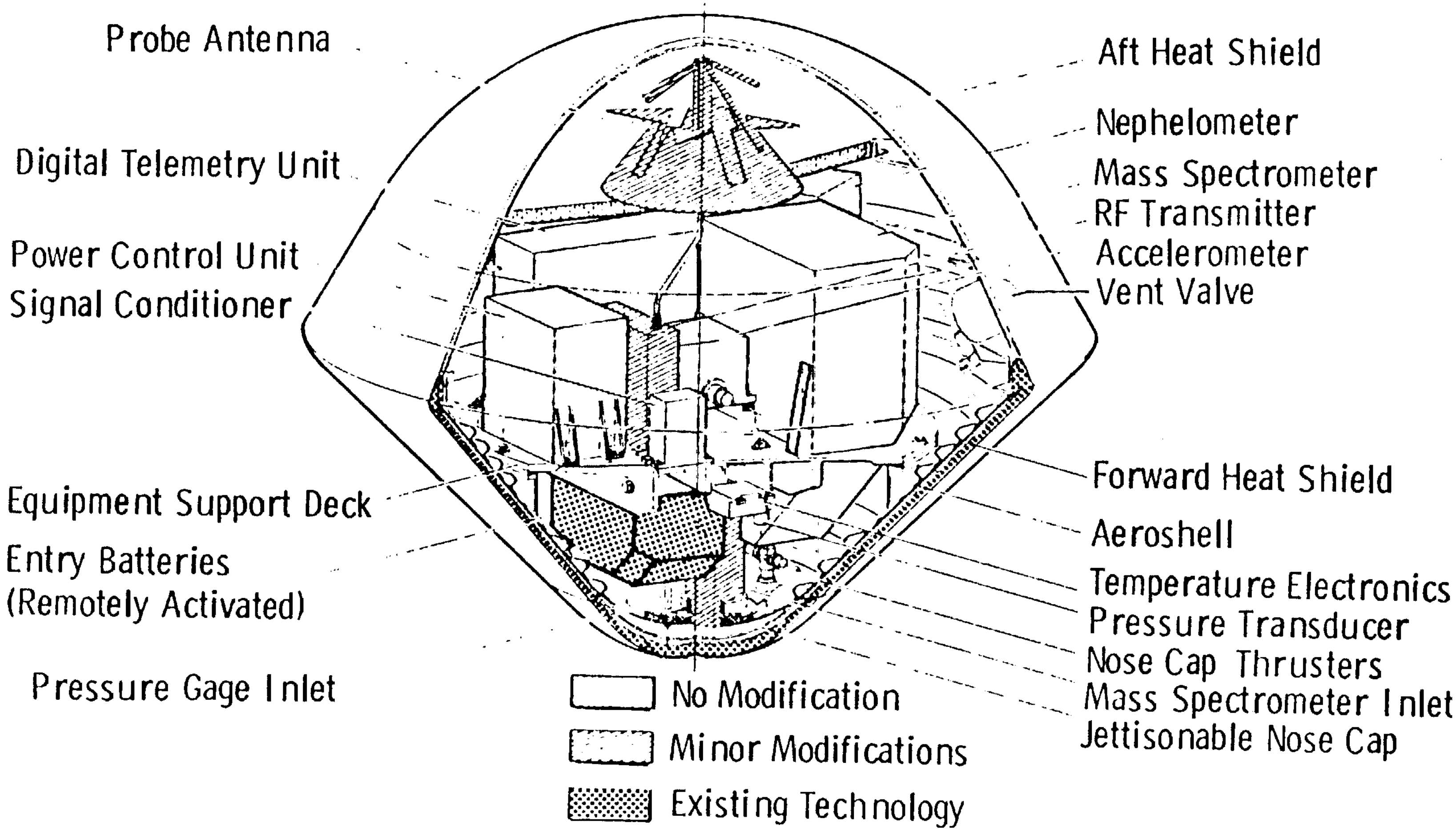

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FIGURE 4-39

possibility of using off-the-shelf or existing hardware; or in the case of science, the hardware that is being developed and specified for the Pioneer-Venus program.

The two items that are not existing hardware are the heat shield and the batteries. For a Uranus probe mission with a seven year duration, you will need remotely activated batteries.

There has been much discussion today about heat shield technology. It does appear that the carbon phenolic type heat shield may be sufficient for the Uranus probe design. The development of this heat shield in the Pioneer-Venus program will provide design technology for the Uranus probe. Hopefully, if some of the uncertainties in the Uranus atmosphere are reduced further, then possibly even more efficient heat shield materials might be sufficient. We have looked at quartz nitrile phenolic heat shield material and it may be a possible candidate.

Most of the general communications type hardware with some modification, can be used directly in the Uranus probe design.

Figure 4-40 presents a summary of science equipment adaptable to a Saturn-Uranus probe. I won't dwell on all of the points, but we did evaluate the specified science for the Pioneer-Venus program. I might say that with no modification or minor modification, you would have to requalify the system for the higher G loads. The design G-level remains to be seen, but is generally going from, say 400 to 600 G's for requalification.

The accelerometers would require modification for greater range because of the higher G's; temperature and pressure essentially can be used as is. The upper range on the pressure scale would not be required.

EXISTING HARDWARE ADAPTABILITY TO PIONEER S/U PROBE

INSTRUMENT	SOURCE	REQUIRED MODIFICATION
ACCELEROMETER TRIAD	PV, LARGE PROBE	MODIFICATION FOR RANGE
TEMPERATURE GAUGE	PV, EITHER PROBE	MODIFICATION FOR RANGE
PRESSURE GAUGE	PV, EITHER PROBE	NO MODIFICATION; EXCESS RANGE CAPABILITY
NEPHELOMETER	PV, EITHER PROBE	NO MODIFICATION
NEUTRAL MASS SPECTROMETER	PV, LARGE PROBE	MASS RANGE MODIFICATION INLET LEAK REPLACEMENT. OUTGASSING VENT TUBE. OTHER SOURCES CONSIDERED.

FIGURE 4-40

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The nephelometer requires no change. The mass spectrometer does present some specific problems. Because of the different atmospheric environment, one would have to change the inlet leak size. For a seven-year period, the outgassing problems just within the instrument would require some sort of venting to obtain the initial vacuum so that the ion pumps would activate. An approach we considered was simply a vent tube that could be opened prior to entry and then sealed off to clear out the ion pump section.

It is more difficult to measure the helium, and a little higher voltage is required to ionize the gas. So there are enough modifications to the mass spectrometer that it is reasonable to consider some other sources; and there are a couple of other mass spectrometers that could be used.

The major modifications are the inlets, the addition of better pumps, and the increased voltage to the ion pump.

Figure 4-41 presents the availability of electrical/electronic components. The main item I want to point out here, is the battery system. As can be seen, we considered various hardware programs that use the typical type of equipment that will do the job for the Uranus probe. However, the battery is a new design and build; and, again, you do need to use a remote activation type battery.

As far as the G loading is concerned, Martin has tested batteries up to 750 G's under electrical load with no ill effects.

We chose a Viking type antenna which required modification to accommodate the frequency change.

Figure 4-42 presents structural/mechanical component availability. The most significant item here is the heat shield design. It would require a new design and build. However, by using the carbon phenolics, it will be based on existing technol-

HARDWARE AVAILABILITY FOR ELECTRICAL/ELECTRONIC COMPONENTS

ELECTRICAL & ELECTRONIC DESIGN	SOURCE	REQUIRED MODIFICATION
DATA		
DTU	PIONEER F & G	MODIFICATION TO REMOVE REDUNDANCY, CHANGE ROM's AND ADD COAST TIMER.
SIGNAL CONDITIONER	PIONEER F & G	NO CHANGE
POWER		
PCU	MARINER	MODIFY CONTROL CIRCUITS AND UPDATE UNIJUNCTION TRANSISTORS. MODIFY WIRING TO ADD G SWITCH.
BATTERY	NEW DESIGN & BUILD	EXISTING TECHNOLOGY
COMMUNICATIONS		
TRANSMITTER	TELEDYNE	STANDARD UNIT MODIFIED FOR MODULATION CHANGE
ANTENNA	VIKING LANDER	MODIFIED FOR FREQUENCY CHANGE.

FIGURE 4-41

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HARDWARE AVAILABILITY FOR STRUCTURAL/MECHANICAL COMPONENTS

MECHANICAL & STRUCTURAL DESIGN	SOURCE	REQUIRED MODIFICATIONS
HEAT SHIELD	NEW DESIGN & BUILD	EXISTING TECHNOLOGY
MECHANISMS		
CABLE CUTTER PIN PULLERS	TRW PROGRAMS	NO MODIFICATION
BALL-LOCK RELEASE PINS	TRW PROGRAMS & MINUTEMAN	NO MODIFICATION
PYRO THRUSTER	HI SHEAR	NO MODIFICATION
THERMAL CONTROL		
ISOTOPE HEATERS THERMAL BLANKET	PIONEER SPACECRAFT	NO MODIFICATION
FOAM INSULATION	SATURN II	NO MODIFICATION
NITROGEN GAS ASSEMBLY	NEW DESIGN & BUILD	EXISTING TECHNOLOGY

FIGURE 4-42

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ogy. That might be a little optimistic in that earth reentry testing may still be required to qualify the heat shield material. Langley people have been talking of this test which would use a launch vehicle with upper staging and provide test data that more nearly fits the conditions that are required.

The other item, thermal control, includes components that were incorporated in our design and no new technology is involved.

The nitrogen gas assembly is a thermal control concept in which gas is released into the entry vehicle internal system during descent to keep out the atmospheric gases up a few bars of pressure. This subsystem is simply an engineering design-and-build effort.

Figure 4-43 summarizes our study conclusions: design of a common Saturn-Uranus probe is feasible and practical and this includes design for the extreme atmospheres of both planets. In the case of this study, with the Pioneer spacecraft, and by comparing item for item, it appears that approximately 85 percent of existing hardware can be used in the Uranus probe design. Now whether or not that is the best design remains to be seen. The only qualification to the 85 percent figure is that the components would have to be requalified for the higher G's and any unique temperature environment combination. However, based on discussions of atmospheric uncertainties at this meeting, it appears likely that the design entry G levels may be reduced from current requirements somewhat.

It can be expected that a reasonably low-cost program can be developed using this approach. In fact, it is necessary that we keep the cost down because of the constrained budgets of today. However, there are some things that should be done and should be done soon to enhance the mission reliability and further reduce the cost of these programs.

CONCLUSIONS

- DESIGN OF A COMMON SATURN/URANUS PROBE IS FEASIBLE AND PRACTICAL.
- PROBE HARDWARE COMMONALITY WITH EXISTING FLIGHT SYSTEMS CAN BE AS HIGH AS 85%.
- PROBE HARDWARE COMMONALITY CAN RESULT IN A LOW COST SATURN/URANUS PROBE PROGRAM.
- ADDITIONAL DEVELOPMENT EFFORTS:

  1. HEAT SHIELD ANALYSIS AND TEST
  2. REMOTELY ACTIVATED SILVER-ZINC BATTERIES
  3. MASS SPECTROMETER INLET AND PUMPING SYSTEM
  4. THERMAL INSULATION MATERIAL TESTS.
  5. HIGH g PACKAGING CONCEPT TESTS.

FIGURE 4-43

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These additional development efforts are listed. The first is the heat shield analysis and test. Additional analysis is required and the upgrading of the test facilities and the flight-type entry testing are certainly desirable, if not required. Again, the remotely activated silver-zinc type batteries for the seven-year mission duration for Uranus are required as well as the mass spec items that were discussed including the inlet and pumping systems. Thermal insulation materials should be investigated within the hydrogen-helium type environments, for applications where they may be exposed at the higher pressures. The environment would certainly tend to affect the thermal insulation characteristics. Finally, the high G packaging concepts proposed for this design should be tested.