Mike Pessin:

One of the changes that was made on super light tank was to go to a square waffle pattern instead of longitudinal Ts, this is known as an *orthogrid*. McDonnell-Douglas had flown *isogrid* (triangular patterns) on their Delta series launch vehicles; and they had done some research on the square waffle, but nobody had flown a square waffle on a pressure vessel. It had been used on payload shrouds, which are unpressurized.

The timing of the proposal – Martin proposed four years – and this was questioned by the Level-2 folks, whether they could do it in four years. I brought out the point that the initial external tank was delivered in four years. Martin was given the contract in September of ’73 and delivered the main propulsion test tank in September ’77 – and that included going into an empty factory with no work force, no subcontractors, no design! And I felt that if they could do that in four years – they should be able to do a modification in four years.

Martin had sold the production rights to this alloy to Reynolds Aluminum, and Reynolds started to try and make the alloy. The first lots they made did not have the same fractured toughness that the Martin material did – *fractured toughness* is the resistance to failure under a fracture kit condition, or resistance to tearing if you want to put it that way. So we went to Reynolds and said: “Why don’t you do a design of experiments?” and they said: “What’s that?” And we had to teach them how to do design of experiments.

When the forming house tried to stretch-form the aluminum-lithium gores as opposed to the 2219 gores, they ran into problems. When they tried stretching the aluminum-lithium with the, in a T3 temper, it broke the stretch press; the films look like an earthquake, and the energy release almost took the roof off the building. So, the first step was: we had to learn how to form the parts; and this involved a rather radical change in the forming process.

The general consensus was: that this was a viable candidate to go forward with – even though the material was very, very early in its development stage. Martin Marietta at one time had their own aluminum company; when they sold the company, they kept the R&D labs and recognized the need for a higher strength weldable alloy – so they were working on an aluminum-lithium family called *Weldalite*. This alloy was still in the labs and only a small amount had been made in the pilot plants, but the hope was that this material would be useful in our proposal.

If you want to go to TRL level – you know, Technology Readiness Levels – I never saw a number for this material. I don’t know what the TRL level was. But we had pretty good confidence that the material was going to be available.

Going in – I guess from a personal standpoint – I didn’t know enough about it to be scared. But I think we certainly didn’t understand as much as we thought we did! Johnson waited 4 months

before they turned us on, but kept the end date the same – so we were starting the program with a 44-month schedule instead of a 48-month schedule.

Multiple weld repairs – it's not unusual for them to crack – but these cracks are so wide open you could read a newspaper through them, and it was totally outside of any of our experience. So Martin decided to convene a giant meeting of all the welding people in the Martin corporate empire, which included Oakridge (they operated Oakridge), so they had a lot of experience in welding big nuclear containment vessels. They had people come in from a number of the different Martin organizations including Martin-Denver – who had built 300 Titans, welded 300 Titans, and we also brought in the Edison Welding Institute:

- they're the outfit out of Columbus, Ohio;
- they're the top welding people in the U.S.;
- they maintain a total repository of all the welding data in the U.S.; and
- they work closely with the British Welding Institute (who are some of the very top welding people in the world also).

When we presented the data to them and they looked at it, they said: "You're never going to learn to repair this material," and we said "Can we change weld wires –well, a different weld wire (these are fusion welds, so they used a weld wire)?" and they said: "No, changing weld wires won't help." So:

- we couldn't make the material,
- we couldn't form it, and
- we had great difficulty in repairing it, and
- we had difficulty welding it.

Now the last challenge we had to face is: that this material tends to be *anisotropic*. Anisotropic means that the material is not the same strength in all three axes: typically aluminums in the strength of rolling – in a *rolling* direction – have the highest strength; across rolling have a, which is known as the *long transverse* direction, have a lesser strength but still very high; and then through the thickness is the s*hort transverse*. Well, this material had an extremely low short transverse stress and it was more nearly equivalent to composites. Composites have a low short transverse stress, but the fibers in the composites don't carry the load; whereas, the resin is what's carrying the load in the short transverse. So we had to *adapt* the analysis techniques that had been developed for composites to use them on aluminum.