

Jan 12 – Why the probe's architecture was an invitation to disaster

OPTIONAL ADDENDUM -- The following technical discussion is an add-on to this advisory and can be skipped -- or quoted in its entirety.

18. This mixed-pedigree nature of the tanks underscores the mongrel ancestry of the probe, that may be the root cause of the original launch flub.

19. The Russians boasted that the probe was the heaviest interplanetary vehicle ever launched, but they cheated on the statistics. This is because they counted the entire weight placed into parking orbit as the weight of the probe [and its fuel] itself.

20. Nobody else ever does this. The practice is to have a third stage [say, a 'Centaur' stage] in parking orbit with the probe. The third stage then fires, sending the probe into interplanetary space. Once it separates from the used-up last stage, it is in autonomous flight. THAT vehicle is the probe, and its weight is all that should be counted.

21. As the Russians built 'Phobos-Grunt', it got too heavy for the first booster, so it was switched to a more powerful one. That booster now had some excess performance capability, so designers decided to keep it attached [with a large fraction of unused fuel] to the third stage, after heading out towards Mars, and then use that same engine to slow the craft into its 'capture orbit' around Mars ten months later. The actual probe would THEN separate from the booster and perform its landing on Phobos.

22. This also allowed the probe itself to 'gain weight' for better equipment, and to find room for a Chinese hitch-hiker probe.

23. The drawback was that the third stage's regular control computer, designed for short-term orbit tug-boat tasks near Earth, was unsuited for interplanetary flight, such as radiation levels and immensely greater distances. So using the stage for the maneuver at Mars arrival meant a new control computer was needed.

24. The solution was to use the original computer of the probe itself to ALSO perform all third stage commanding, both at the beginning of the flight AND at Mars arrival. The third stage's tried-and-true control computer and all its radio gear were ripped out, and replaced with cables linking it to the probe sitting on top of it. And of course the cables had to have disconnect latches to unhook safely once it would be jettisoned after Mars arrival.

25. Adding the "third stage" to the probe itself allowed the Russians to brag it was the 'heaviest interplanetary probe ever'. But of course it wasn't -- they were fudging the figures by counting weight that every previous deep space mission had honestly book-kept as 'third stage'. It was a propagandistic technicality -- but it was related to a dangerous design reality.

26. Karma is cosmic. The kludged-together design failed at the very first step it tried to take. After safely reaching parking orbit, the probe computer began configuring the probe for deep-space cruise, unfolding its solar panels, using its own jets to turn to face the sun, and sending housekeeping data back to Earth. But on the very first pass across Russia,

an hour and half after launch, Mission Control also noticed a puzzling anomaly.

27. The probe was supposed to coast for a few hours in sun-pointing mode, until the scheduled time of the rocket firing of what was once the 'third stage' [now officially part of the spacecraft itself]. It would then turn itself into a small-end-forward orientation and light the engine.

28. Meanwhile, during periods in Earth's shadow, when the sun-sensor was not getting a direct view of the sun [i.e., knowing where to point], it was supposed to 'hold inertial attitude' until sunrise when the sensor could again precisely aim at the sun.

29. But Mission Control noticed a strange thing at sunrise, which occurred during the first tracking pass across Russia. The probe had drifted FAR from the sun-pointing attitude that it had attained immediately after launch. With the now-functioning sun tracker seeing the sun, at 'dawn' it began a rocket-controlled twist in space, back to facing the sun as it had been supposed to be doing.

30. An hour later, over South America, it was supposed to fire its engine to begin its Mars journey. It never happened. The engine never fired. And when the probe crossed Russia again, it wasn't reporting back via radio. The control computer had gone insane.

31. The leading presumption is that the control software in the probe's computer, now responsible for commanding the 'third stage' after its original flight computer had been ripped out, had encountered some condition that prevented triggering of the rocket firing. And in such a situation, it was supposed to go to 'safe mode', report such to earth, and wait for instructions. But it didn't.

32. If the computer wasn't doing what it was supposed to do, it sure looked like it was doing something it was NOT supposed to do. Over the next ten days, in a gradual process that astonished and baffled ground observers, the probe slowly but steadily raised its orbit, a few hundred feet at a time. This was totally unprecedented for an 'inert' satellite.

33. The least impossible explanation for this behavior was that somehow the probe was rocking back and forth, turning itself towards the sun or towards the engine ignition orientation, each in turn as night turned to day turned to night in orbit. This twisting in space, when controlled by rockets, also could have slightly nudged the station higher, and it seemed to be happening in the same point along its orbit, after sunset [that's why the effect accumulated along only one side of its orbit]

44. Ten days later, the mysterious creep stopped short. It didn't gradually ease off and vanish. One day it was a steady as always, and the next day it was utterly gone.

45. The only explanation that makes sense is that the 'attitude control fuel' allocated to the probe's control computer for use in the first few hours of flight had finally been exhausted. Those tanks were empty. And the probe began its inexorable decaying descent under atmospheric drag. The orbit never changed in any mysterious way, ever after.

46. At about that point, ground trackers were finally able to get some signals back from the probe. But they were never more than "I'm ali-i-i-i-ive" acknowledgments -- no usable telemetry ever was received.

47. Two features of the probe made it so hard to talk to in its parking orbit. Clearly, the planners had never expected to be stuck in parking orbit, even though that's exactly where they got stuck on the LAST Mars mission in 1996. And clearly there had been last-minute nervousness about that eventuality when a Russian scientist had asked South American amateur astronomers to go outside during

the scheduled rocket burns and eyeball the probe to see what happened.

48. First feature -- the communications handshaking protocol was complex, to prevent unauthorized control of the vehicle. But exchanging the right passwords and secret grips was a time-consuming process taking up to ten minutes. On the long slow cruise to Mars, there's plenty of time. But in low Earth orbit, the probe speeds across the sky in only a few minutes -- and then sets so quickly, there isn't enough time to perform the standard authentication protocol.

49. Second feature -- the backup comm antenna was mounted on the bottom of the booster stage, which would be facing back towards Earth on the outbound leg. But in another incomprehensible crossed signal, a design kludge had stepped on the toes of this system.

50. To get some additional oomph out of the booster stage, designers had to increase its fuel load. Rather than redesigning it and stretching its tanks, they just strapped on an auxiliary set of tanks at the back end, arranged in a ring around a hole through which the regular engine could fire. But these tanks, according to private Russian accounts, largely blocked the emergency antenna already installed there.

51. The plan was to fire the engine first to drain those tanks, then shut down in an intermediate orbit reaching ten thousand miles into space. Then the tanks would be jettisoned, and on the next pass across South America, the engine would be burned a second time to push the probe onto its interplanetary path.

52. Jettisoning the ring of 'drop tanks' would also unblock the emergency comm antenna at the end of the stage, for any need on the outbound cruise.

53. The designers just never seemed to consider they might need that emergency antenna BEFORE being safely inserted onto the outbound cruise leg.

54. Over a period of fifteen years, the probe was built and rebuilt to follow a series of design and mission changes, tailoring itself to each new requirement without adequate consideration of which design features were based on earlier requirements, some now obsolete.

55. There's probably no chance this probe will be rebuilt and launched in the future, with any resemblance to the vehicle that is about to 'demise'. That's because if they start from scratch, they will design it differently -- and a whole lot smarter.

56. The mission goal deserves trying again. But THIS mission serves only as a shining example of how NEVER to try to accomplish it, again.