The Space Congress® Proceedings

1997 (34th) Our Space Future - Uniting For Success

Apr 29th, 2:00 PM

Paper Session I-A - Risks and Trade-Offs for Unproven Launch Vehicles

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Risks and Tradeoffs for Unproven Launch Vehicles

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Abstract:

AMSAT, The Radio Amateur Satellite Corporation, has launched over 30 amateur radio satellites. Most have flown as piggyback payloads where excess payload capacity was not required. Many have flown as test payloads for new launch vehicles on their test flights. The Phase 3-D satellite is scheduled for launch in the second half of 1997 as the primary payload for the Ariane 502 launch vehicle. This paper will discuss the risks and tradeoffs associated with flying on an unproven launch vehicle, insurance issues, and past successes and failures for those 30 satellites.

AMSAT has always relied on the kindness of the aerospace industry. While amateur radio operators have been building their own satellites since the beginning of the space age the generosity of government agencies and launch services companies has always been necessary for rides to orbit. While amateur satellites are typically fairly small payloads (10 to 50 kgs. range is normal) there are a lot of them. In terms of numbers amateurs are Arianespace's best customer with sixteen completed launches.

When NASA was launching its own expendable launch vehicles there were many opportunities for small piggyback satellites. The second stage of the Delta rocket has excellent capabilities for mounting a separate payload, either one which remains attached to the Delta, or one with its own separation system so it can fly on its own. After the Delta's upper stage and payload are sent on their way the second stage can be commanded to do additional burns to put a secondary payload in to a more desirable orbit. So that was a rather appealing situation, and many early amateur satellites were launched on NASA's Deltas.

With commercial companies now launching the majority of satellites the situation has changed. Most commercial satellites are launched in to geosynchronous transfer orbits, and there is no excess launch vehicle capacity. If the satellite doesn't use all of a launch vehicle's capacity, then the excess energy is used to put the satellite in to a more optimal transfer orbit than normal, which results in additional useful lifetime for the satellite.

There are a couple of government launches each year which do have excess capacity though, and amateurs try to use those opportunities whenever possible. Unfortunately those opportunities are more the exception than the rule, and there are many other small satellite manufacturers and users who also desire those opportunities.

So AMSAT is always looking for any potential ride in to space. Some esoteric possibilities which have been examined include getaway special launches from the space shuttle, ejections out of Mir's airlock, tether deployments from both the shuttle and Delta, and even a small box-shaped satellite which an astronaut could toss overboard during a spacewalk.

A launch vehicle doesn't necessarily have to be going the correct direction, some amateur satellites have their own propulsion systems which can convert the initial launch orbit in to the desired operational orbit.

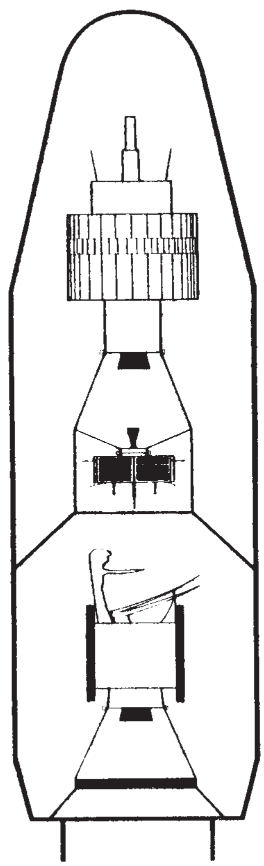
One of the best opportunities is test launches of new launch vehicles. In most cases a test launch of a new launch vehicle is considered to be riskier than a normal operational flight, so it's offered at a discount in recognition of that added risk. If a new company without any track record is launching a brand new launch vehicle then it's got a lot to prove. Few commercial customers are willing to risk their million dollar satellites on an unproven vehicle, and government agencies are even more nervous about risking their one-of-a-kind multi-million dollar satellites. Nobody wants to risk their ultra-valuable one-of-a-kind satellite. So AMSAT gets to risk its no-quite-as-valuable one-of-a-kind satellite instead.

AMSAT's Experience With Test Launches

All of the Phase 3 satellites have been scheduled for test launches of Ariane launch vehicles because of the excellent relationship the AMSAT German chapter (AMSAT-DL) has with the European Space Agency. And the Phase 3 program has had much more than its fair share of excitement.

Phase 3-A was assembled by U.S. hams and volunteers at the Goddard Spaceflight Center. Components came from around the world for integration, and the satellite was shipped down to French Guiana for launch on the Ariane L02 test flight. Unfortunately two minutes after launch the satellite was on the bottom of the ocean due to the launch vehicle failure.

Phase 3-B (OSCAR 10) was 3-A's replacement. It was launched on Ariane L06 on June 16, 1983. Spacecraft separation took place properly, but upper stage of the launch vehicle recontacted the satellite a couple of minutes later. This unintentional collision resulted in a damaged antenna and a nutation to its spin. After frantic recalculations and commands the ground controllers were able to successfully command one engine burn. But the satellite ended up in an incorrect orbit. While it was a shaky ride the satellite has turned out to be an incredible performer in space. Its computer was 'fried' by excess radiation so it can't be commanded anymore. Its batteries failed, but fortunately they failed open instead of shorting out. So the satellite is only usable on its low gain (omnidirectional) antennas, and only when the spacecraft is in sunlight - but when it's on, it continues to work well, over 13 years after its launch.



Ariane 401 launch configuration - Meteosat, Phase 3-C, and Panamsat - AMSAT illustration

Phase 3-C (OSCAR 13) was launched on the first test flight of the Ariane 4 launch vehicle. In comparison with the excitement of the previous Phase 3 launches everything went perfectly. The sister passengers on the Ariane 401 launch vehicle were the MOP 3 European meteorological satellite and Panamsat 1, the first privately owned international communications satellite. It's interesting to note that Panamsat was not able to obtain insurance at an acceptable premium, because it was a test launch. So the satellite owner decided to accept the risks and launch it anyway.

Ariane V22 (401) launch carrying Phase 3-C - photo by Arianespace

Phase 3-D, currently under construction in Orlando, is scheduled for launch on Ariane 502, the second test flight of the Ariane 5 launch vehicle. The launch opportunity and the launch date have both changed many times. At one point Phase 3-D were supposed to fly on the Ariane 501 vehicle. Later the plan was to fly Phase 3-D, the ESA Atmospheric Reentry Device (ARD), and a commercial communications satellite on Ariane 502.

The commercial slot would be offered at a discount since it was a test launch and Intelsat was interested in using it for their 802 satellite. Under that arrangement Phase 3-D would fly as a secondary payload on the launch of another Intelsat satellite on an operational Ariane 4 vehicle. Delays in the Ariane 5 project and the loss of the Intelsat 708 on a Long March caused Intelsat to back out of the 502 slot, choosing the more prudent business decision of sticking with more reliable proven launch vehicles. After the Ariane 501 failure ESA decided to add an additional test flight. So Ariane 503 will carry the ARD and a discounted commercial customer, and Phase 3-D will be the primary payload on Ariane 502.

When Phase 3-D's assembly was started three years ago the anticipated launch date was April 1996. That date has gradually slipped due to delays in the Ariane 5 development program and the Ariane 501 failure. While the delays gave additional time to complete the satellite and test it more completely, it has increased its cost. AMSAT has very few physical 'assets' and borrows, leases, or contracts resources as needed for projects. So every month's delay to the Phase 3-D launch results in additional expenses to keep the laboratory doors open and to pay the bills. This is one of the key tradeoffs which anybody who wants to fly on a new launch vehicle must realize - delays by the launch vehicle cause delays and more expense to the satellite project.

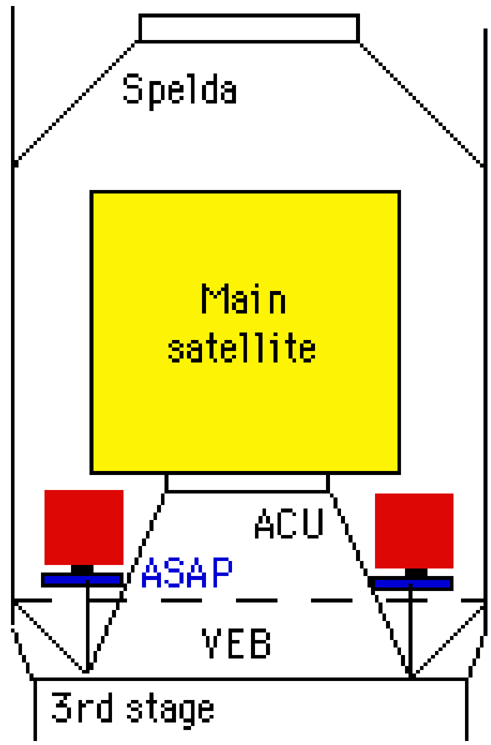
While Phase 3-D is the primary payload on Ariane 502, it is not the primary mission objective. There will be two large spacecraft-simulators which will be instrumented to measure the launch vehicle's flight environment. The primary objective for the Ariane 502 mission is to prove to the aeorspace market that Ariane 5 can put payloads in to geosynchronous transfer orbit reliably.

AMSAT has received detailed information on the 501 accident and the corrective actions so there's a lot of confidence in the Ariane 502 launch vehicle. Most importantly ESA needs to show the world aerospace community that Ariane 5 is a reliable launch vehicle.

Unlike previous test flights this time AMSAT was expected to carry its share of the load. In the past a 'launch contract' would be quickly made up and signed a couple of days before the launch on a rather informal basis. For the Phase 3-D launch AMSAT wanted a much larger class satellite, and ESA wanted a more equitable return. AMSAT will pay approximately $1 Million to the European Space Agency for the launch of Phase 3-D. It's less than the price for an operational mission, but certainly not as low as what amateurs have paid in the past.

The Phase 3-D launch contract specifically requires that a ballast payload is available, in case the satellite is not ready in time for the launch. If Phase 3-D get delayed, the ballast gets launched in its place, and AMSAT still pays for the launch. So this puts additional pressure on the spacecraft integration team to make sure that it's ready on time.

In 1987 AMSAT member Jan King came up with the concept of using empty space in the Ariane launch vehicle below the primary payload for microsat launches. There was just enough room to squeeze in a platform with up to six satellites. ESA and Ariane agreed and came up with the ASAP (Ariane System for Auxilary Payloads).



Typical ASAP configuration - Arianespace diagram

For the first ASAP launch AMSAT was only charged the integration costs, which came to about $150,000. There were six microsats on the first ASAP mission - OSCARs 14, 15, 16, 17, 18, 19. They were launched as as piggybacks on the Spot 2 launch. This was a rather unusual situation - a test launch for the ASAP on a proven launch vehicle. Whenever amateur payloads fly with a primary payloads there are certainly concerns that the little payload won't hurt the big payload. So even though the microsats are tiny in size, the paperwork isn't any less. Items like how fast will the microsatellite outgas, whether or not its transmitters will affect the primary satellite, etc. are all concerns which have to be dealt with each time. Ariane V35 was launched on January 21, 1990 with Spot 2 and the microsats. Spot 2's separation took place 17 minutes after launch. Then the third stage performed its backaway maneuever, and each microsat was ejected in sequence. The ejection springs had slightly different forces, permitting the satellites to go in to slightly different orbits.

The second ASAP marked the first sales of commercial microsats by Arianespace. There were three microsats without any amateur involvement and OSCAR-22, built by the University of Surrey. In some ways this can be thought of as the first "commercial" launch of an amateur satellite. The satellite owners negotiated a commercial launch services contract for an ASAP launch with Arianespace. OSCAR-22 is actually a multiple mode satellite, with both amateur and commercial transponders.

The 1992 launch of TOPEX/Poseidon also featured two microsats, the S 80/T and Kitsat-A. Kitsat was paid for by South Korea and includes both amateur and non-amateur capabilities. As an amateur satellite it's known as KO-23. S 80/T was a commercial payload also using the ASAP's capabilities.

In 1993 four amateur satellites plus Healthsat were launched as ASAP payloads. The amateur payloads were sponsored by Korea, Italy, Portugal, and a U.S. firm.

To date 21 small satellites have been launched using ASAP. So Arianespace has made profits from the sales of ASAP launches, and gained an additional marketing tool for its commercial geosync comsat launches. In some cases Arianespace has successfully bid for commercial launches by offering a free launch of a ASAP class payload. While most comsat users rarely have a need for this type of a requriement it can be donated to an educational or scientific organization. Overall, the development of the ASAP has benefited everybody, except Ariane's competitors.

The Russian RS-15 amateur satellite was launched aboard a test flight, the four stage version of the START launch vehicle. START is a converted ICBM which was originally built as a Cold War strategic weapon and now beaten in to a plowshare as a launch vehicle. While the launch was successful and RS-15 is in operation the last stage of the launch vehicle exploded after the spacecraft separation. It didn't hurt the spacecraft, but did raise concerns about the vehicle's reliability.

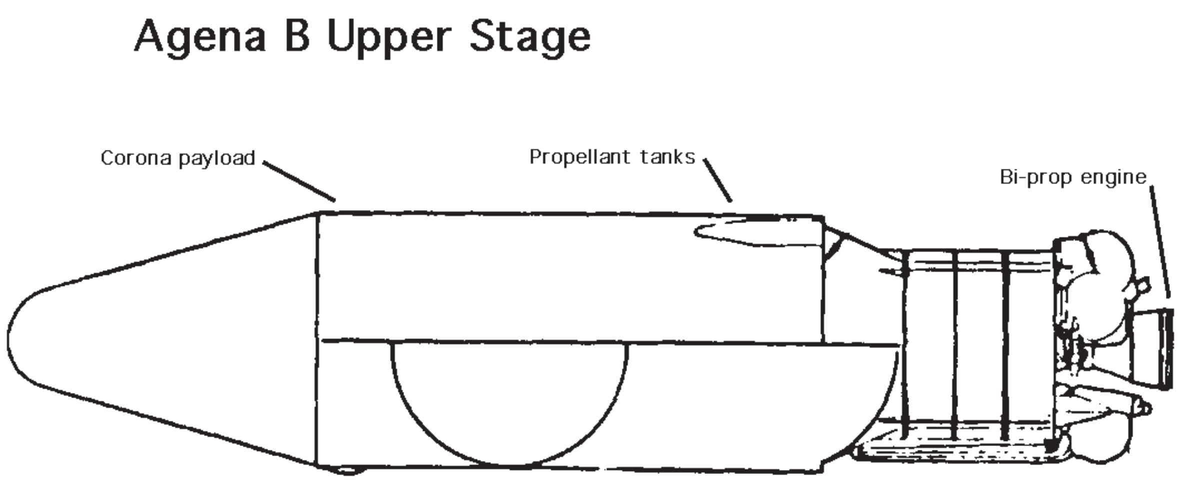
The second launch of a START vehicle was the five stage version. It was originally supposed to carry a Russian scientific satellite, plus piggyback payloads from Israel and Mexico. The primary payload had a schedule slip and couldn't make the planned launch date. Instead of delaying the launch the Russians chose to fly a dummy ballast in its place, so the two paying customers (Israel and Mexico) could get their payloads in to orbit on schedule. This was a rather extraordinary situation - launching a vehicle with only a small fraction of its planned payload because of Russia's economic situation and requirements for hard cash. The START vehicle was launched on March 28, 1995. Unfortunately the vehicle failed during its third stage burn and both payloads were lost. The University of Mexico paid $70,000 out of a planned $120,000 for its launch.

1995 was not a good year for new launch vehicles in general. Other unsuccessful launches that year included the loss of the APStar 2 satellite on a Chinese Long March 2E, the loss of the STEP 3 on a Pegasus XL, the partial loss of Koreasat 1 on a Delta, the loss of Gemstar 1 on a Lockheed Launch Vehicle, and the loss of the METEOR spacecraft on a Conestoga launch vehicle. There was also an unique partial failure. A German reentry vehicle was launched on a small Japanese launch vehicle. There was a failure in the launch vehicle's second stage and everybody assumed that the payload was lost. However a year later it was discovered that the payload had achieved orbit, rentered safely, and ended up in a distant portion of Ghana! With the exception of the Delta all of the losses can be attributed to new launch vehicles without proven track records.

Other AMSAT launches:

Besides test launches there have been other cases where amateurs have been able to find launch opportunities.

The first four OSCAR satellites were launched by the Air Force. OSCAR 1 and OSCAR 2 were launched as piggyback payloads with Corona (Discoverer) spy satellites. The payloads were mounted on the upper stage of the launch vehicle, replacing ballast.



Corona with Agena upper stage

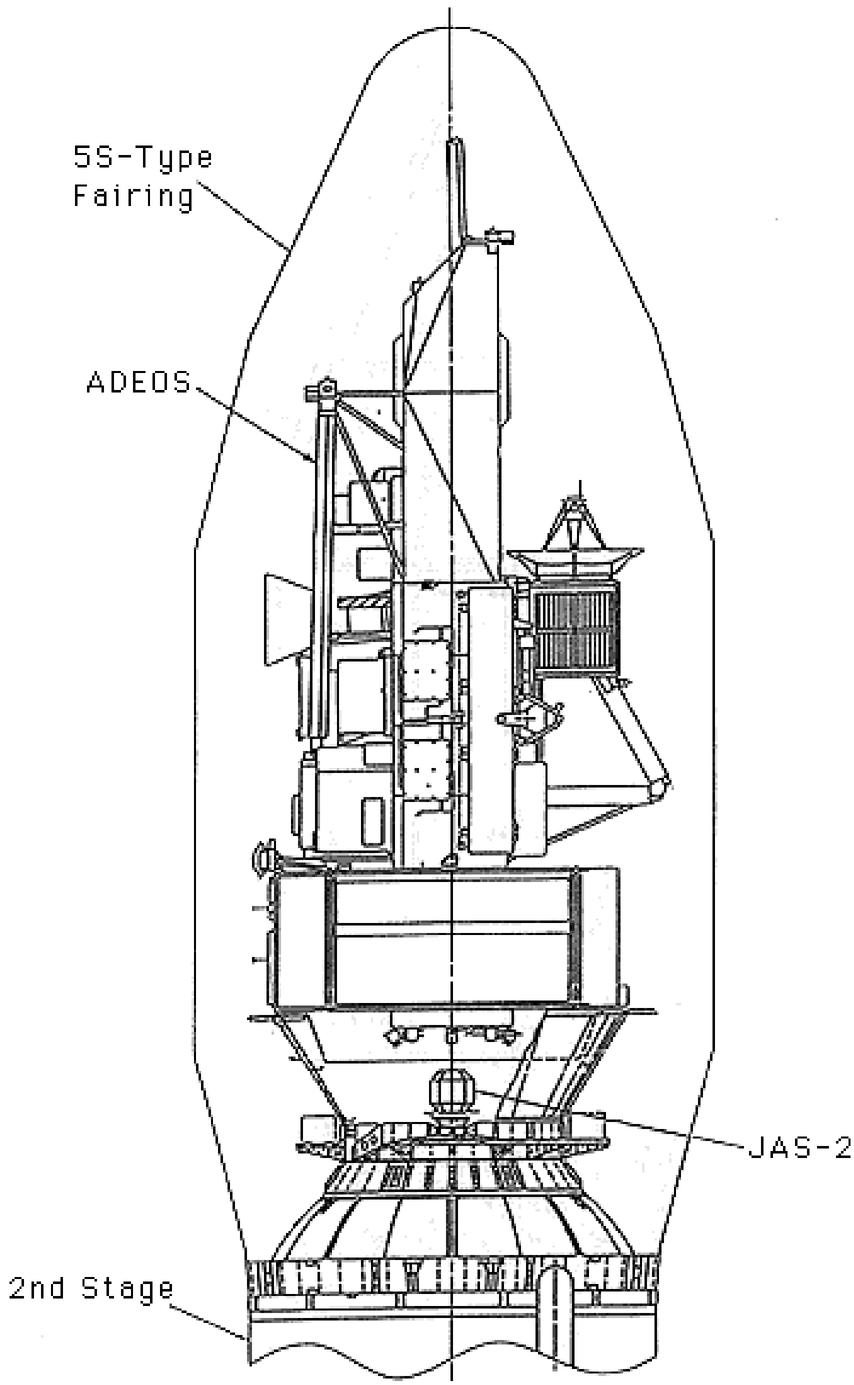
OSCAR-3 was launched with seven other small payloads on an Air Force Thor-Agena launch vehicle.

OSCAR 4 is the only amateur satellite to date to be launched from Florida. It was launched with three Department of Defense satellites on a Titan IIIC. The vehicle was supposed to go in to a circular geostationary orbit, but the failure of the launch vehicle's upper stage resulted in all four payloads stranded in elliptical geosynchronous transfer orbits. Even though this wasn't the planned orbit, the satellite was put in to operation and used by some hams.

As previously noted NASA Deltas were used to launch several amateur satellites. OSCAR 5, 6, 7, 8, 9, 11 were all launched as Delta piggyback payloads. The upcoming Sunsat and SEDSAT are also scheduled for upcoming Deltas.

UNAMSAT 1B, the replacement for the unsuccessful UNAMSAT 1A launch, was launched on a Russian SL-8 Cosmos launch vehicle under a commercial launch services contract. This time their launch cost $220,000, but at least it was sucessful.

Japan has launched its own rockets in two distinct programs, a series of solid propellant rockets which were developed in Japan and the N-1 series which was a licensed version of the NASA-McDonnell Douglas Delta. Later versions of the N-series and H-I used less American-designed components and the current H-II is a soeley Japanese design. The OSCAR 12 (FO-12) and OSCAR 20 (FO-20) satellites were launched on H-Is and OSCAR 29 (FO-29) was launched on an H-II as secondary payloads.



ADEOS / JAS-2 launch configuration

Most of the Russian-built amateur satellites have been ‘piggyback transponders’. Instead of building an entire satellite, the Russian ham community will just obtain a transponder, and make arrangements to attach it to a ‘mother satellite’. The primary satellite provides power, attitude control, thermal control, and housekeeping functions. It’s always acknowledged that as a secondary payload the amateur transponders take backseat in priority to the primary payload, and if the controllers choose to shut off the main satellite, then the amateur payload gets shut off too.

Arsene (OSCAR 24) is a special case. It was built by French amateur radio operators and launched on Ariane as a secondary payload.

Which brings us up to date. It’s important to note that even though the majority of the thirty two amateur satellites have been put in to orbit on test launches of new unproven launch vehicles only two have been lost due to launch vehicle failures. This 94% launch vehicle success rate is comparable to the commercial launch services industry at large, so AMSAT has been extremely lucky to keep down its losses to such a reasonable figure.

Insurance issues:

It’s a long standing myth that you can’t get insurance for test launches of unproven launch vehicles or non-commercial satellites. You can get insurance for almost anything - including Betty Grable’s legs and Jimmy Durante’s nose - provided that you’re willing to pay high enough a premium. What you can’t get is insurance at a reasonable rate which you’re willing to pay.

On the other hand, you’ve got to take a closer look at the _reason_ for insurance. What it’s there to protect.

Businesses purchase insurance to protect themselves against the potential lost income if there’s a failure. As an example, Hughes Communications had contracts with Showtime, Nickelodeon, MTV, TVN, and other companies for their shares of the Galaxy 9 comsat. Even though the combination of a Delta launch vehicle with an HS-376 satellite is the most reliable in the world (16 successes out of 16 tries) and both the Delta and HS-376 have long term reliable track records Hughes Communications chose to purchase insurance just in case there was a bad day, to protect itself against the potential lost income from its customers. Insurance companies consider the Delta/HS-376 combination to be at least 95% reliable, but typically will charge around 16% for a premium. The difference between the anticipated loss rate and the premium is the operating expenses, profit, and other costs of doing business for the insurance companies. In any case, Hughes Communications felt that they needed insurance for the Galaxy 9 mission and that the rate was acceptable.

On the other hand NASA typically chooses to self-insure its launch vehicles and satellites. If a specialized one-of-a-kind scientific satellite is lost then all the insurance money in the world won’t replace the lost science, and couldn’t possibly keep all of the scientists busy and active while a replacement is built.

The AMSAT situation is similar to NASA's. Even if an insurance company offered us an incredibly low rate, the question remains what to do with any insurance payoff if it did occur? The money could be given back to all of the individuals, corporations, and governments around the world who have contributed to the project, but that doesn't really make sense - if all any contributor wanted was the money back then it wouldn't have been contributed it in the first place. The money could be used to try to build a replacement satellite, but that makes the assumption that the resources would still be available for the replacement, including people who may have moved on to other projects, and that it's possible to find substitutes for many of the one-of-a-kind parts which were obtained through luck on the original project.

Conceivably the companies which manufacturer amateur radio transceivers which are designed for satellite work, movable high gain antenna systems, and similar hardware would be interested in obtaining launch and satellite activation insurance because they stand to lose the most - if an amateur satellite fails for any reason then they'll lose business.

What does make sense for amateur satellite manufacturers is to purchase additional parts, spares if you will. In many cases parts have to be purchased in minimum quantities, even if only one or two components is need. So there is already a decent inventory of generic and specific parts at little additional cost. If the satellite's successful then the spares can be used for the next project. If the launch vehicle fails, or the satellite has a premature failure, then a backup satellite can be completed in much less time than it would take to build one from scratch. It would still be necessary to build many one-of-a-kind assemblies and find substitutes for others, but it would still be much better than starting from scratch.

When David Liberman built the UNAMSAT satellite he ordered spare parts for everything. The cost for the additional parts was a small fraction of the original spacecraft - so in effect he had an almost free self-insurance policy. UNAMSAT 1A was lost in the START 1 failure, but UNAMSAT 1B was launched just 15 months later because of his foresight.

It took five years from the time the UNAMSAT project was started until the UNAMSAT-1A's unfortunate loss. But only one quarter of that time to find a launch for its replacement.