ATACMS Block II First Flight

On Schedule, On Cost, On Target!

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An Army Tactical Missile System (ATACMS) Block II missile flew for the first time Oct. 16, 1997. Approximately 200 seconds into the flight, the missile came apart at the seams. Skin panels came off the payload section, and its contents were flung in all directions into the airstream. Cause for alarm? Hardly. The Block II missile had just completed its first successful dispense of 13 inert Brilliant Anti-armor (BAT) submunitions.

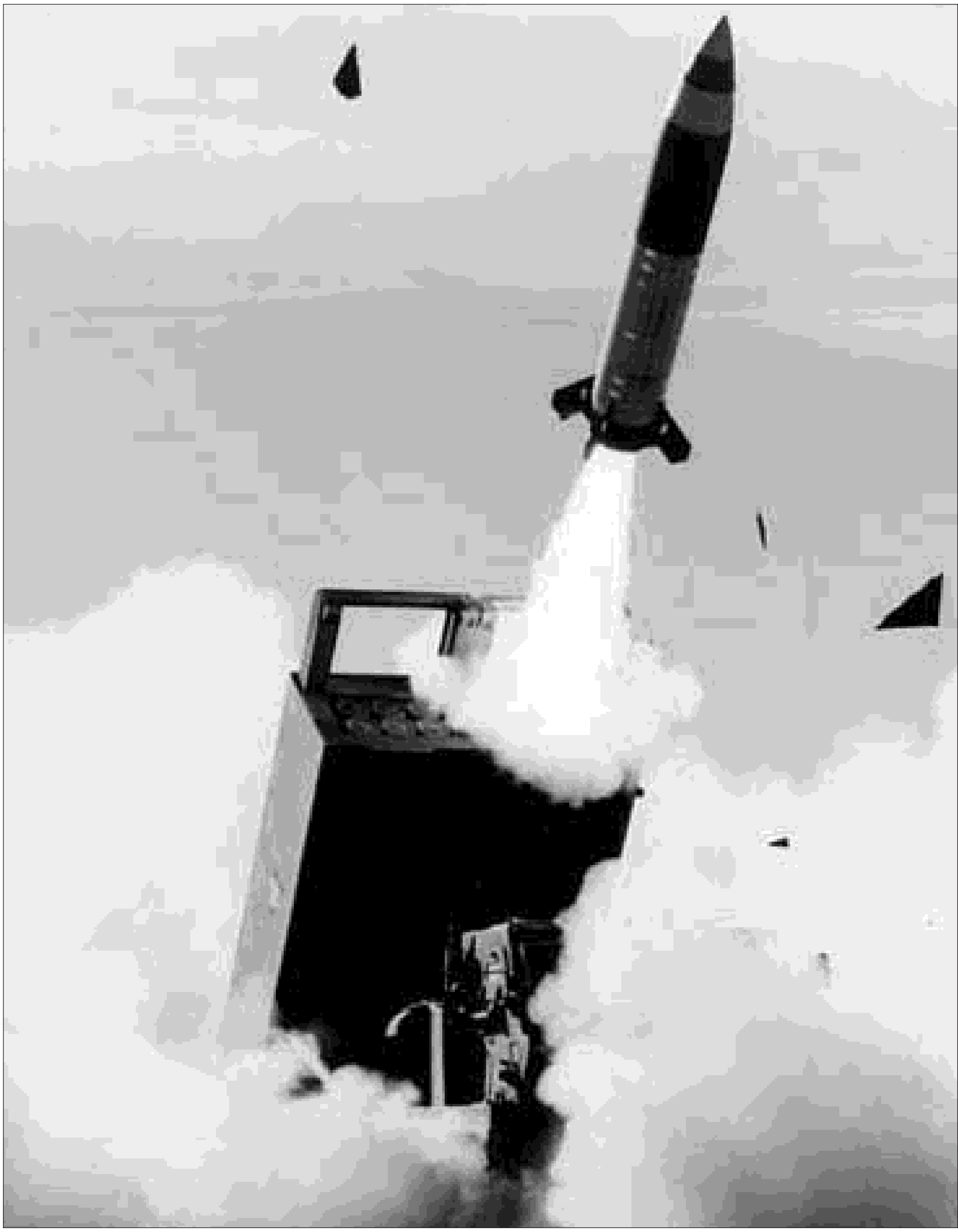
Two Flights, Two Firsts, Two Successes

As with any new program, there were critics who doubted this would work. Most expressed concern that the submunitions would crash into each other. Although this flight eliminated many concerns, there were still doubters. Could it be repeated? Would tactical BAT submunitions survive the dispense environment?

One month later, on Nov. 19, 1997, any remaining doubts were put to rest. The Army launched the second Block II missile against a moving armored column 70 miles away. This time, the missile payload contained a live tactical BAT. After another perfect dispense, the first live BAT dispensed from the missile, acquired, tracked, homed on, and impacted a moving vehicle. Two flights, two firsts, two successes.

Successful Convergence of Two Major Programs

These flights occurred two years into the missile program, on schedule and on budget. They represented the successful convergence of two major programs —the ATACMS missile and the BAT sub-



The Army Tactical Missile System (ATACMS) is a conventional surface-to-surface artillery weapon system capable of striking targets well beyond the range of existing Army cannons, rockets, and other missiles. ATACMS missiles are fired from the Multiple Launch Rocket System (MLRS) M270 weapons platform. ATACMS was very successful in Operation Desert Storm.

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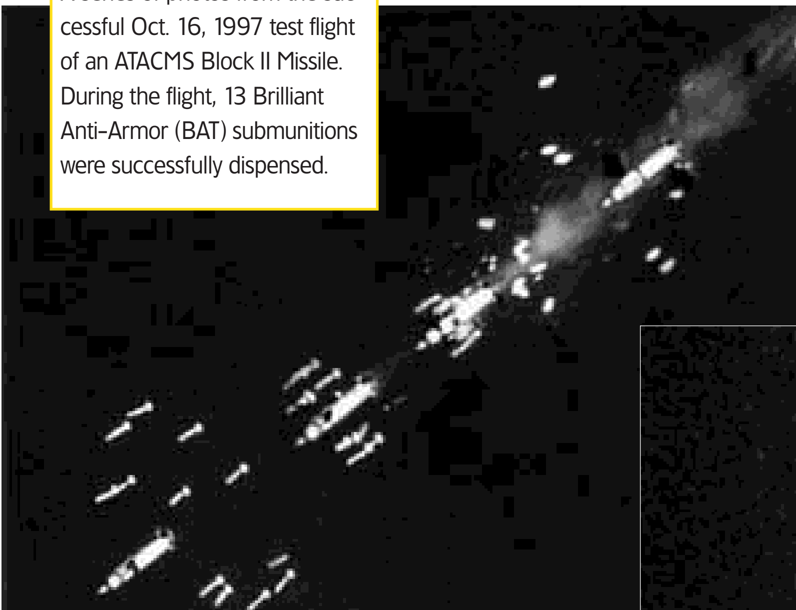
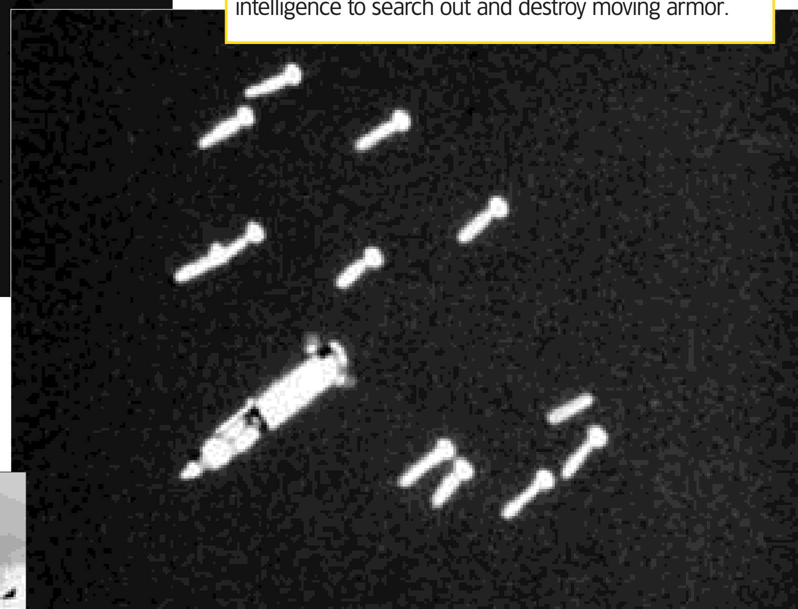
Photos courtesy Lockheed Martin Missiles and Fire Control — Dallas



A series of photos from the successful Oct. 16, 1997 test flight of an ATACMS Block II Missile. During the flight, 13 Brilliant Anti-Armor (BAT) submunitions were successfully dispensed.



Lockheed Martin Missiles and Fire Control conducted a successful test flight of an ATACMS Block II Missile Oct. 16, 1997. The ATACMS Block II Missile will have a range of more than 80 miles (128 km) and will carry 13 BAT submunitions. The BAT submunition is produced by Northrop Grumman and has the lethality and intelligence to search out and destroy moving armor.

Fired from the dual-capacity Multiple Launch Rocket System (MLRS) M270 Launcher, ATACMS provides operational fire support throughout the depth and breadth of a battlefield.

munition. Despite many developmental and integration issues that had to be resolved along the way, the flights remained on schedule.

This article attempts to examine the things we did that led to this remarkable success. It will explore some of the reasons behind our success in expectation that some of our successes may be applicable and transferable to other programs. At first blush, some will seem obvious; maybe all of them will. However, we don't always implement the obvious for one reason or another.

My belief is that the following eight tenets played a major role in our achievement of a successful First Flight.

- Early Start
- Teaming Does Work
- Think Outside the Box
- Success is in the Details
- Test, Test, Test
- Treat Success with Suspicion
- An Informed Customer is the Best Customer
- Subcontractors are Our Friends

The remainder of this article presents an item-by-item discussion of these tenets.

Early Start

One of the most beneficial keys to success was something that wasn't under our control. The Army TACMS-BAT Project Office recognized the benefit of early work leading to the award of a development program. In our case, three funded studies occurred prior to the development contract. In Phase I, we examined design feasibility. In Phase II, we fabricated a generally representative dispenser and then conducted a sled test. Finally, in Phase III, we developed a prototype tactical payload section, followed by a series of dispense tests.

One lesson to come out of this early effort is that success and failure are relative and must be viewed in the long term. Phase III testing revealed that our skin severance system was not compatible with the Northrop Grumman-developed BAT submunitions. We also learned that the dispenser design had three significant problems: lack of radial symmetry during dispense, excessive roll rate from several payload locations, and excessive acceleration in the dispense direction.

Viewed from the standpoint of Phase III, these results might have indicated a failure of the design. However, the Phase III activity was beneficial in that it provided a baseline from which to start the development effort, and it uncovered problem areas with the skin separation and dispenser concepts. This allowed problem solving to begin right away, once the development contract was in place, and significantly reduced dispenser development time. The first-flight schedule could never have been maintained had these problems been uncovered after the development program was underway.

Another way of looking at this is to identify risks early and address them first. Sometimes actual testing is not feasible, and in this case a good risk assessment should be performed as a minimum. Plus, a good risk assessment will help you and the customer determine where early dollars are best spent.

Teaming Does Work

We were only the second major program at Lockheed Martin Missiles and Fire Control – Dallas (LMMFC-D) to institute Integrated Product Teams (IPT). We came online at a time when there was not much company history about what was right or wrong about IPTs or even how to make them work most efficiently.

Our philosophy, which worked well for us, was to keep the number of teams to a minimum. We chose to form teams along the lines of major new products or subsystems. Initially, the teams were Payload Section, Improved Missile Guidance Set/Sequencer Interface Unit, Missile Software, Launcher and C2, and Flight Termination and Telemetry. Later we added a Simulation and Performance team for two reasons: 1) because the simulation was a deliverable (i.e., product); and 2) to mirror the Project Office's internal organizational structure.

We assigned IPTs the responsibility for designing, analyzing, testing, documenting, production engineering, and producing configuration items within the cost, performance, and schedule requirements of the Block II program. For example, the payload IPT was responsible for integrating the structure and skin separation and dispense systems with the interfacing items such as the solid rocket motor, the guidance section, the BAT submunitions, and the Enclosure Assembly Launch Pod. IPTs were led by a senior engineer who served as Cost Account Manager for the respective elements under development.

LMMFC-D's program management was via the Program Integration Team, which was led by the Block II Program Manager. This group met weekly to review status, assign action items, and resolve conflicts between teams. It was composed of the Program Manager, the IPT leads, and the functional (engineering, manufacturing, quality) managers as well as key support areas such as Finance and Configuration Management. The Project Office and our associate contractor (BAT developer) were invited to participate on all teams, and the major subcontractors participated on their respective IPTs.

One lesson learned is that teaming is not a synonym for meeting. Too many fail because they don't recognize this simple fact. A key benefit of teaming is supposed to be increased communication. Don't forget there are ways to communicate besides sitting in meetings all day.

To facilitate integration with the BAT submunition and enhance communication between LMMFC-D and Northrop, a Northrop office was established on-site and manned nearly full time during the first year and a half of the program. Northrop rotated engineers through the office based on the most pressing item of interest at the time. This on-site access to key individuals played a major role in resolving differences and maintaining schedule for the first flight.

The teaming process was successful at all levels. For instance, there were no live BATs to be dispensed on the first flight. LMMFC-D and the Project Office's engineering staffs proposed flying the missile to a nontactical dispense altitude in order to capitalize on the capability of White Sands Missile Range (i.e., instrumentation) to obtain dispense coverage unavailable on tactical flights. This idea was presented to the government's Test and Evaluation Integrated Product Team (T&E IPT) for approval. The T&E IPT was highly receptive to the idea and approved the Test Plan change. The result was stunning video and camera coverage of the skin separation and dispense events, and conclusive visual confirmation that these critical events worked as designed.

Think Outside the Box

One thing to guard against is a "that's the way its always been done" syndrome. It comes in many related forms and is a general reluctance to make or even evaluate change. After all, if it's not broken, don't fix it – right? Thinking outside the box is the antidote for this attitude.

Our missile's role – essentially a bus to transport submunitions – had led to the idea that it was not a "maneuvering" missile. At the beginning of Block II, a simple pull-up was used to slow the missile prior to dispensing the BAT submunitions. A new-to-the-program engineer, unencumbered by history, suggested and developed a much better energy management approach. This approach involved coning the missile at sometimes-large angles of attack. This was so successful that it produced a relatively constant environment for dispense over a wide range of launch conditions and provided better (X2) control of terminal conditions.

It was pretty startling the first time we saw this maneuver during flight-testing.

The days of thinking of our missile as nonmaneuvering were definitely over.

Another example of this type of thinking relates to teaming on a larger scale. Honeywell was selected to develop the Submunition Interface Processor (SIP), a card to go into the Missile Guidance Set the company already manufactured. Our schedule was such that we needed a prototype much sooner than Honeywell could deliver one. Part of Honeywell's problem was their unfamiliarity with the processor we needed for the SIP. The unique solution was to develop the design as a team. LMMFC-D engineers were responsible for the basic board layout and function, while Honeywell engineers participated in part selection and producibility considerations.

After we completed and checked out the prototype, the entire responsibility for the SIP shifted to Honeywell. This arrangement was very successful. We had the desired prototype in time to support early software development, and Honeywell had a design that worked and was compatible with their manufacturing process.

Success is in the Details

Block II was fortunate in that this was already an Army TACMS business area culture. It originated with the Business Area Executive and flowed down through the management structure. At all levels, managers were taught to pay attention to the details. This tends to keep small problems from becoming big problems and is one of the primary reasons Army TACMS has been so successful historically. This philosophy was carried into our weekly Program Integration Team meetings.

We began daily status meetings 100 days prior to first flight. Generally, these meetings lasted less than an hour, and the primary focus or topic varied from day to day. All parts (down to the nut and bolt level) and tasks required to support the flight were tracked. Nothing was assumed too trivial to identify its status. This level of detail is essential as the flight date approaches because so many things must happen at a specific time, and seemingly minor hiccups can have significant consequences. Good scheduling is a must during this time.

Treat success with suspicion. Analyze all test results – even apparently successful results – as if a failure had occurred. This level of detail applied across the board will often uncover surprises that could be problems down the road.

Test, Test, Test

A thorough, progressive test program is a must. The sooner subsystem and system problems are uncovered and resolved the better, and schedule impact is minimized.

We begin our testing at the component level and proceed through subsystem to system level. Our electronic and software items progress from component testing to the software lab to the Design/Test Support (electronic integration) lab to real-time Hardware-in-the-Loop (HWIL) testing before flight test. All electronic boxes go through HWIL before each development flight.

Integration testing with real hardware is essential to success. When we first tested a BAT in our integration lab, we discovered the BAT communication protocol was not as specified in the System Interface Specification. In other words, the BAT was communicating differently from the way the missile software had been designed. This discovery occurred barely three months prior to the flight date and had the potential for a major slip in schedule. Fortunately, a major effort from our software team modified the missile software in time to keep the flight date. Had we relied on the way it should have worked instead of testing, the initial flight with a live BAT would have been a failure.

One of our rather unique tests involved full-scale testing of the skin separation system in a wind tunnel. One skin panel was separated (due to tunnel constraints) on each run. This testing allowed us to verify this critical event at actual flight conditions and provided timing information for the skin kicker bag system (forces skins away from missile) that could not have been obtained any other way. We also learned that the kicker bags needed to stay with the skins because, otherwise, they would blow by the stowed BATs and damage their wing and fin retention straps. Had we not done this, we would have had several BATs fail on each flight and probably not have been able to resolve why (in-flight camera coverage is not sufficient at dispense to resolve this level of detail).

We learned a valuable lesson the hard way late in the test program. This did not impact the first flight, but it is significant enough to cover here. The Block II missile carries 13 BATs; 10 in an outer ring and three in an inner ring. Sequencing of the dispense event is controlled by the Sequencer Interface Unit (SIU). Normally, the missile's skin panels are separated, followed by dispense of the outer-ring BATs and finally dispense of the inner-ring BATs. On our tenth and last flight, the inner ring was prematurely commanded to dispense barely one second after launch. The SIU was designed with three levels of protection built in to prevent premature/inadvertent dispense. We learned there were periods of time very early in the flight where two of the three could be easily defeated. This coupled with a failure (a short in this case) caused the inner ring to dispense prematurely.

We also learned two key lessons from this. First, we had focused on the performance of the SIU in the region of time where it was supposed to be functional. Here the behavior was normal. Had we looked in detail over the entire flight time, we would have observed the anomalous behavior early in the flight. Second, we should have performed some tests in a failed condition, such as the short. This testing also would have revealed the problem.

Treat Success with Suspicion

A former manager once passed on what I consider exceptional advice. He was referring to flight test results, but I have found his advice valid for all testing. He said to analyze all test results – even apparently successful results – as if a failure had occurred. He was addressing the tendency to form a quick opinion and move on when something looks successful and comparing that with the digging we do to understand and explain failure. *This level of detail applied across the board will often uncover surprises that could be problems down the road*.

However, this "treat success with suspicion" attitude must come from the top. Program management sets the stage for what is expected. But once the environment or expectation is established, I find that it is self-sustaining.

An Informed Customer is the Best Customer

No one would argue that good customer relations are not important to the success of any program. Customer trust is not something that happens overnight, but over a period of time. Our philosophy was to pass as much information to the customer as possible. The program manager, chief engineer, and IPT leads were on the phone several times a week with their counterparts in the Project Office. One benefit of information free-flow is that it minimizes Project Office overreaction to negative events. It also provides more lead-time for the Project Office to help with problems or potential problems instead of reacting to them.

One area that benefited from the team environment was the System Interface Specification, which defined the interface requirements between the BATs and the missile. LMMFC-D, Northrop, and the Project Office worked this document jointly.

Know when to cut your losses and drop an under-performing subcontractor or go to a second source before cost and schedule get away from you. Knowledge is time. By staying aware of the subcontractor's situation, you buy time to either fix the problem or move on to something else.

Another key to the success of the first flight was the fact that the Project Office's acting Product Manager and his chief deputy attended our weekly Program Integration Team meetings for a couple of months prior to the first flight. They heard firsthand the status and problems. After the meetings, they would often "walk the floor" and discuss issues directly with the engineering teams. This made communications with them much easier the rest of the week due to their depth of knowledge.

Subcontractors Are Our Friends

When you stop and think about this, it makes perfect sense. Good lasting relationships – among friends or subcontractors – are based on familiarity and trust. Each relationship is unique and therefore, will be treated a little differently based on its unique characteristics and needs.

One thing that is important is to know a subcontractor's product as well as they do. This allows you to make informed decisions regarding schedule issues, design changes, or test results. More than once, subcontractors made use of our expertise to resolve potential show stoppers. One of our second-source subcontractors went through a period where they relied on one of our engineers to help resolve technical performance issues with their product. We stayed the distance with them, and the result was a design that met the requirements for about half the cost of the original supplier.

The flip side of the coin is in knowing when to cut your losses and drop an under-performing subcontractor or go to a second source before cost and schedule get away from you. Knowledge is time. By staying aware of the subcontractor's situation, you buy time to either fix the problem or move on to something else.

One time when knowing our subcontractor paid off occurred when we were driven to examine alternative concepts for separating the skin panels. One of these concepts used high-pressure gas to inflate a flattened steel tube. The stroke of the tube as it expanded to its original circular shape provided an energy source. We used the stroking action to fail fasteners. We began with a sub-scale demonstration of the concept to verify that it would indeed fail fasteners. This being successful, we proceeded to more complex testing.

An interesting lesson occurred when we went out for bids to develop the Flat-to-Round skin separation system. Function time was our most critical technical requirement. Of the two vendors who submitted bids, one had a substantially lower function time based on what seemed to be sound assumptions. This vendor won the competition but was not the one who had initially explored the concept with us and performed the proof-of-principle tests.

The first component-level test after contract go-ahead was a total disaster. The tubes ruptured at the ends and failed to break any fasteners. It seemed as if the basic physics of their concept was wrong. Naturally, this caused a lot of concern, but what could have been an ugly situation was ameliorated by our trust and confidence in their technical staff. The subcontractor was allowed to work through this and ultimately developed a concept that met all the requirements and did not impact the development schedule. Obviously, there was increased attention and oversight, but no panic.

Block II had two major subcontractors. They both produced quality products. But, as mentioned earlier, they had their differences and each needed handling differently. One was undermanned and tended to let paperwork slip. Great attention needed to be focused on ensuring Subcontractor Data Requirements List deliveries were on schedule. An on-site representative at this contractor was a big help in that he could provide ready assessment on the status of activities at the contractor's facility.

The other subcontractor was relatively small and was weak in some areas of analytical capability, particularly the analysis of large-scale structures. In this case, we used some of our own resources to bolster the subcontractor's and let him focus on his strengths. This was quite successful.

Our IPTs were arranged around products, so the IPT was the primary interface with the subcontractor. The IPT lead was the principal technical contact and, in conjunction with the IPT, provided technical direction to the subcontractor. The Materials organization was still the only entity that could issue formal (contract) direction, but Materials was a part of the IPT and participated in its activities. We found weekly teleconferences with subcontractors to be beneficial. IPT members at LMMFC-D and the subcontractor would participate. Often, we would three-way with Project Office engineering. All necessary personnel were on hand to resolve issues quickly, and the whole team was aware of the big picture and status.

Frequent on-site Technical Reviews are another useful tool. There is a tendency to shy away from this with today's communications capabilities such as video-teleconferencing; however, face-to-face meetings are still the most productive.

Success Doesn't Just Happen

Mission success is not something that just happens. It requires continual attention. The foundations for success must be established in the beginning by creating the right environment. By paying attention to the tenets for success presented here, a government or industry team's chances are greatly enhanced.

Editor's Note: The author welcomes questions or comments on this article. Contact him at **billy.brassell@lmco.com.**