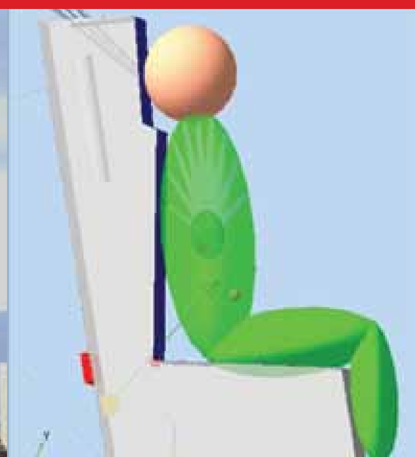
CASE STUDY

MSC Software: Case Study - Patrick Air Force Base

MSC Adams Extends the Military’s Ability to Improve Ejection Performance and Safety



Ejection seats must work perfectly every time they are used in an enormously wide range of altitudes, aircraft motion profiles, wind conditions and pilot weights while at the same time taking manufacturing variation into account. Physical testing of course plays a pivotal role in ejection seat design but time, cost and safety limit the number of situations that can be tested to far fewer than the number of potential ejection scenarios. Analysts at the Naval Surface Warfare Center (NSWC) at Indian Head, Maryland, and the 45th Space Wing at Patrick Air Force Base, Florida, have developed a model of an ejection seat using MSC Adams rigid body simulation software. During the model’s initial 5-year joint-force development process, Adams was the first professional dynamics software used to completely model the complex physics involved in the deployment of an ejection seat.

“The Adams model has provided a significantly higher level of understanding of ejection seat deployment,” said Sean Stapf, Ejection Seat & Rocketry Analyst for the 45thSpace Wing. “We have used the model to investigate incidents where the ejection scenarios were not understood until they were reproduced in the simulation, to analyze the effect of possible manufacturing variations and guide a number of design improvements such as arm and leg restraints that were recently added to ejection seats. The ability to accurately simulate their complete operation from cradle to grave has revolutionized our ability to improve ejection seat performance and safety.”

Key Highlights:

Industry

Aero

Challenge

Improve ejection performance and safety

MSC Software Solutions

Adams to model the complex physics involved in the deployment of an ejection seat

Benefits

- Accurate Simulation
- Reliable Analysis
- Improved Design Process

“Adams has played a major role in the substantial improvements that have been made in the performance and reliability of the ejection seats used in military aircraft over the past decade.”

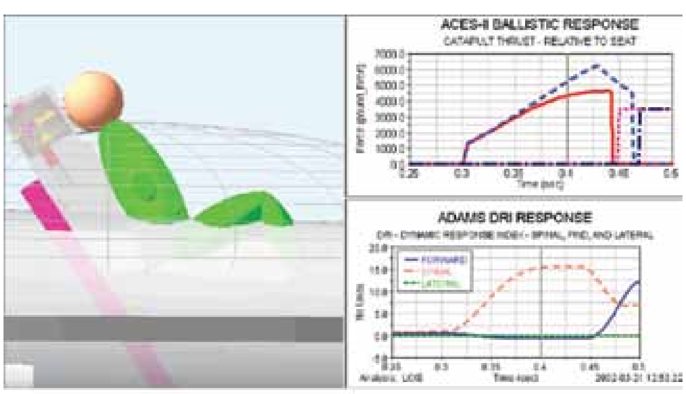
Sean Stapf, Patrick Air Force Base, 45th Space Wing

Physical Testing Essential but not Sufficient

The CKU-5 rocket catapult is used with the ACES II ejection seat as the aircrew escape ejection system on A-10, F-15, F-16, F-22, B-1 and B-2 aircraft. Ejection seat testing at both the component and full-assembly level are the primary tools for the conceptual design and validation of ejection seat performance. For example, sled testing can be used to capture important data such as the trajectory of the seat and resulting accelerations on the manikin representing the crewmember. However, the wide range of possible ejection seat operation scenarios and the technology and cost limitations of physical testing equipment mean that it is only possible to test a tiny fraction of the possible ejection seat deployment scenarios.

Simulation of an ejection seat is extremely challenging because of the breadth and complexity of the different physical processes that must be accounted for in order to provide accurate results. The most difficult aspects of the simulation challenge include:

- the complex potential motion of the aircraft such as rolling and pitching during the ejection
- accounting for the effects of the multiple rocket thrusters including
  - the catapult rocket that pushes the ejection seat up the spine of the cockpit
  - a sustainer rocket that provides an additional 200 feet or so of lift so that the ejection seat can clear the aircraft tail at high speeds and gain safe recovery at low altitudes
  - if there are two crewmembers ejecting, divergence thrusters are used to move the two seats away from each other
  - a stabilizer thruster fires to offset forward or backward pitching motion
  - another rocket fires to deploy the parachute
  - special purpose energetics are incorporated in some seats to perform functions such as separating the seat from the crewperson, disconnecting drogue chutes, spreading or un-reefing parachute canopies, and removing night vision gear
- understanding the mechanics of the rollers attached to the seats that run in the aircraft tracks behind the seat during the ejection
- incorporating the multiple stages of the ejection process including ejection, extraction and inflation of the parachute, separation of the crewmember from the seat, etc.
- determining the effects of wind conditions including crosswinds, headwinds, aircraft carrier motion, etc.

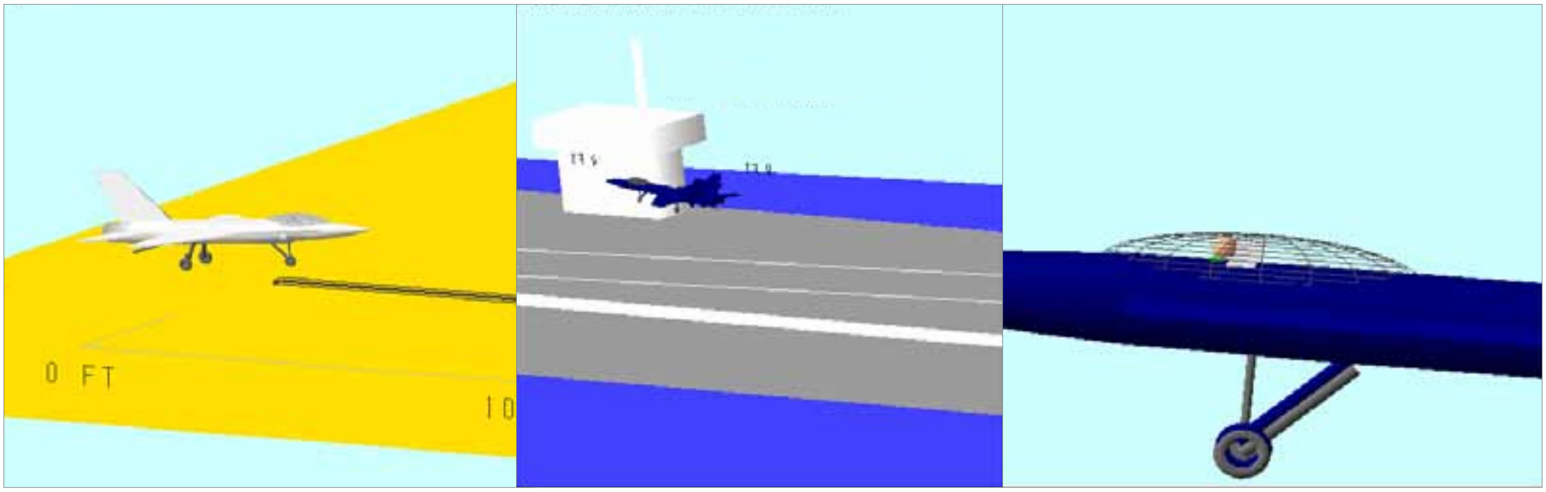


Adams tracks the response of the human body during the ejection simulation and determines the potential for injury.

Finding the Right Software Tool

The military has evaluated and used numerous open source and commercial software packages for evaluating various aspects of ejection seat events. The military has also written six degree of freedom codes designed specially for ejection seat simulation. Most of these codes have proven critical for pioneering the development of the ejection seats, simulating one or several aspects of an ejection event but none had met the goal of simulating the complete process until Adams was used.

The NSWC engineers began developing the Adams ejection seat model in the mid 1990s and the model was completed and validated by 2000. “We researched all of the mechanical parts of the different ejection seats used by the Navy and Air Force as well as British and Russian ejection seats in order to incorporate a complete feature set with the goal of being able to simulate any ejection seat,” Stapf said. The model handles compression of the three



sets of landing gear. A simpler model that only included the aircraft fuselage would not have been able to account for situations where the crewmembers eject while the aircraft is in collision with the ground, driving into the soil during a runway over-run, or arresting on a runway or aircraft carrier cable. The drag load from the parachute is calculated by putting masses around the parachute, expanding the chute and reporting the drag force as a function of the degree of inflation of the chute. The model calculates the dynamic response index (DRI) that indicates the potential for injury at any point in the simulation, combining it into the Air Force's Multi-Axial Dynamic Response Criteria (MDRC). For example, a brief moment of acceleration at 15 g may be tolerated without injury by most of the crew population, but integrating a longer dwell of that same acceleration can identify the potential for a spinal injury. The model has proven the ability to evaluate a wide range of both the ejection scenario, and the variations in the man-seat system that undergoes the ejection.

Adams Used to Guide Design Process

One of the most interesting uses of the Adams model to date was in a case where several upgrades to the design of ejection seats were undertaken simultaneously. One of these changes arose because a small percentage of crewmembers that ejected suffered injuries due to the high-speed windblast that can exert excessive forces on their limbs protruding from the seat. A historical approach has been to add lanyards that secure the crew members' legs and arms as the seat is ejected. The restraints are deployed via a series of lanyards which are pulled through the seat as it moves up the rails during ejection.

At the same time that the arm and seat restraints were being developed to protect the crew as they emerge into the windblast, another design change was made to the catapult thruster to tailor the release profile of its energy. This change was made in order to avoid injuries that can occur within the aircraft; during the initial catapult phase of the ejection. Both of these changes had the effect of reducing the separation velocity and some tests of seats where both changes were implemented showed that seats did not obtain sufficient separation velocity.

Simulation was used to quantify the amount of force that was tapped off from the catapult thruster by the deployment of the lanyards. The results showed that the new thruster rockets worked well without the limb restraints and the limb restraints worked well with the old rockets. Various possible design changes were evaluated without the expense or time involved in building and testing physical prototypes. The conclusion was that the most promising solution to the problem was redesigning the restraints to use less mechanical energy. The solution was verified with physical testing and has already been deployed on many combat aircraft.

"Adams has played a major role in the substantial improvements that have been made in the performance and reliability of the ejection seats used in military aircraft over the past decade," Stapf concluded. "The Adams model has been validated in many physical tests, giving us the confidence to rely on simulation results to evaluate and investigate incidents, determine the impact of possible manufacturing defects and guide the on-going design improvement process."

About MSC Software

MSC Software is one of the ten original software companies and the worldwide leader in multidiscipline simulation. As a trusted partner, MSC Software helps companies improve quality, save time and reduce costs associated with design and test of manufactured products. Academic institutions, researchers, and students employ MSC technology to expand individual knowledge as well as expand the horizon of simulation. MSC Software employs 1,000 professionals in 20 countries. For additional information about MSC Software's products and services, please visit www.mscsoftware.com.

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About Adams

Multibody Dynamics

Adams is the most widely used multibody dynamics and motion analysis software in the world. Adams helps engineers to study the dynamics of moving parts, how loads and forces are distributed throughout mechanical systems, and to improve and optimize the performance of their products.

Traditional "build and test" design methods are now too expensive, too time consuming, and sometimes even impossible to do. CAD-based tools help to evaluate things like interference between parts, and basic kinematic motion, but neglect the true physics-based dynamics of complex mechanical systems. FEA is perfect for studying linear vibration and transient dynamics, but way too inefficient to analyze the large rotations and other highly nonlinear motion of full mechanical systems.

Adams multibody dynamics software enables engineers to easily create and test virtual prototypes of mechanical systems in a fraction of the time and cost required for physical build and test. Unlike most CAD embedded tools, Adams incorporates real physics by simultaneously solving equations for kinematics, statics, quasi-statics, and dynamics. Utilizing multibody dynamics solution technology, Adams also runs nonlinear dynamics in a tiny fraction of the time required by FEA solutions. Loads and forces computed by Adams simulations improve the accuracy of FEA by providing better assessment of how they vary throughout a full range of motion and operating environments.

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