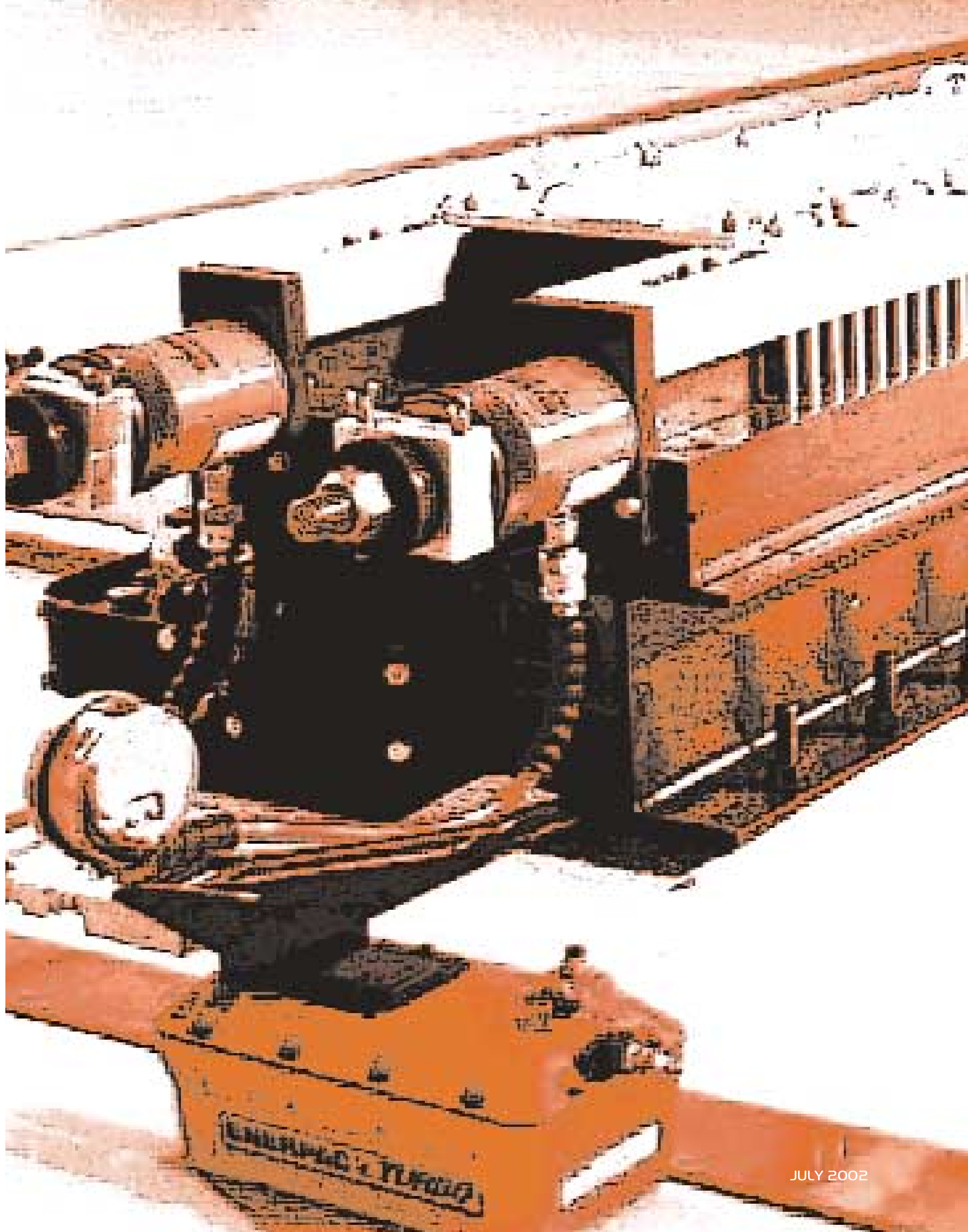
DYNAMIC IMPACT

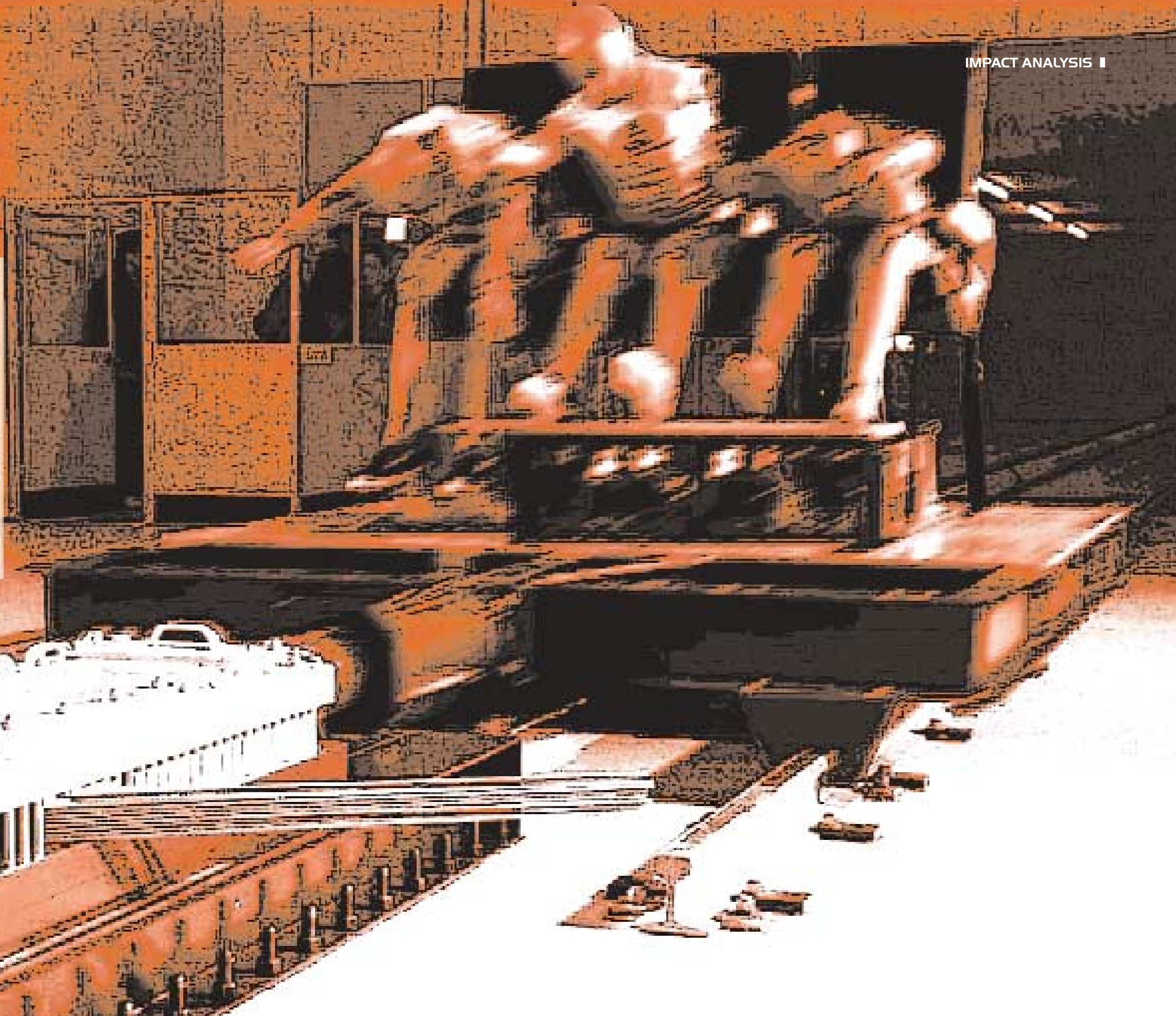
Several options for sled facility ownership and operation have become available to meet the industry's needs. The wire deceleration system has design, cost and performance advantages



Tom Wittmann

The Introduction of dynamic (crash) test regulations into civil aircraft seat systems brought challenges to the industry and created a new demand for devices that could economically and accurately assess seat performance and occupant safety under impact conditions. Seat and restraint suppliers soon learned that the large number of tests required to develop and certify new products, coupled with high test costs at commercial test labs, caused test budgets to skyrocket and justified developing dynamic test capability in-house.

Although there were available test systems used primarily to support the automotive industry, there was no supplier that could provide a turnkey system at the



desired cost/performance level. For some, this led to investment in the design and manufacture of their own facilities. This was quite a challenge when combined with the fact they were still in the process of learning the effects that dynamic testing had on the response of their seats. Fortunately, new options for sled facility ownership and operation have become available to meet the industry's needs.

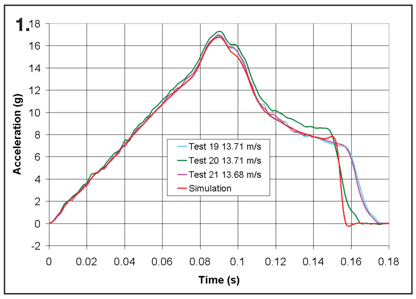
A primary concern in the decision to install a facility is determining the optimum solution for the intended application – in other words, which system has the best cost/performance ratio. Costs and performance are easier to arrive at for purchased systems than for those designed and built in-house, where final cost and performance are not known until after the project is installed. Determining the total cost of the test facility is fairly straightforward and includes both the start-up and operational expenses.

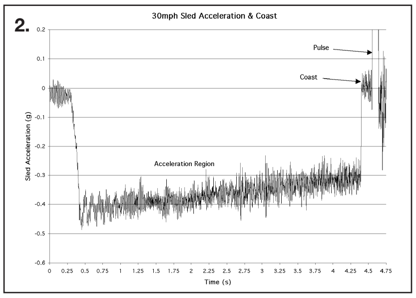
Measuring overall system performance requires an understanding of:

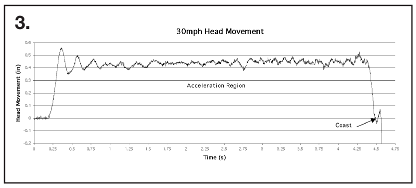
- The system flexibility, or how well it can accommodate all expected payloads in size and mass for the desired test profiles for peak velocity and g forces;
- Predictability based on simple user-defined and controlled inputs;
- Accuracy and repeatability over time;
- Its reliability and ease of operation and maintenance, all of which is a function of system complexity.

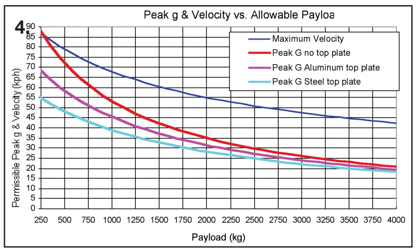
Put simply, performance is a measure of the ability to repeatedly match and apply the desired pulse shape to the test article.

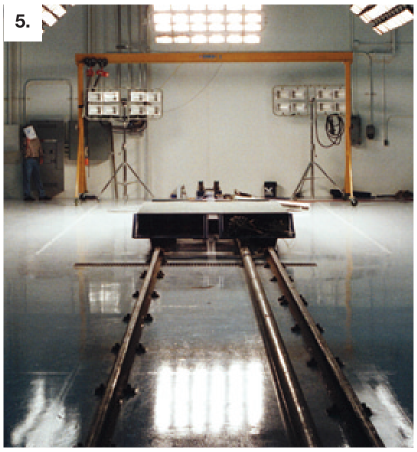
Sled test systems can be configured either horizontally or vertically, and are categorized according to their fundamental method of generating the pulse, which includes reverse acceleration, deceleration and impact with rebound. Each option has its own advantage for cost and performance. For instance, reverse accelerator sleds have a stationary sled prior to impact, eliminating any possibility of dummy movement adversely affecting repeatability, while deceleration sleds have the advantage in performing some specialized tests, such as simulating pre-impact braking conditions. However possibly most important, decelerator sleds are much less



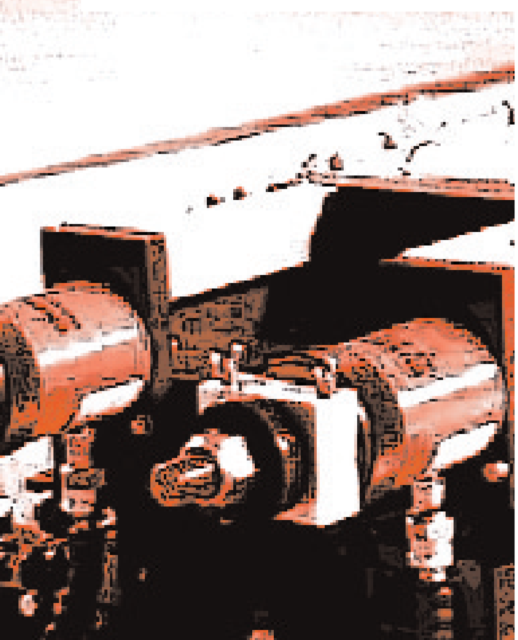








1. 14CFR 25.562 tests with simulation prediction
2. Sled acceleration for a 48kph (44ft/s) impact velocity
3. ATD head movement during sled acceleration phase
4. Performance summary – Seattle Safety decelerator sled system
5. Sled lighting system



expensive to produce, operate and maintain. A summary of some of the more popular configurations and their relative performance measures is shown in Table 1.

For many, and particularly for aircraft seat testing, the optimum choice has been the wire deceleration system, offering the best combination of cost and performance. Several enhancements by Seattle Safety have made them the dominant supplier of sled systems for aerospace testing.

Wire decelerator system

The decelerator in this system uses the proven technique of steel wire rods as the energy-absorbing element. During impact the wire is cold-worked over rollers, each applying a consistent and predictable force to the sled. The Seattle Safety decelerator design has reduced setup time to 15 minutes by allowing the use of straight wires that are all formed in-place by the machine. There are 360 wire locations available, which allows great flexibility in pulse shaping. The sled is accelerated up to impact speed with an air-powered piston following an acceleration profile that causes the least dummy movement for a given system length. The pressure in the accelerator's storage tank is automatically maintained and remotely monitored, and a velocity sensor instantly reports impact sled velocity.

The system has proved to be a popular choice, not only due to its lower costs, ease of use and excellent performance, but because of the option for complete integration of the sled into a fully operational facility. This turnkey system includes simulation software for designing pulse shapes, high-intensity lighting, hardened data acquisition, high-speed video cameras, a three-axis measurement device for determining seat deformation, seat mounting fixtures that provide floor distortion, dummies, instrumentation and a triggering system that synchronizes the data acquisition and cameras, whether on- or off-board.

Seattle Safety coordinates site preparation, and installs the equipment, and trains the operators. The entire operation is painless and fast, allowing accurate cost estimation and tight scheduling.

Performance

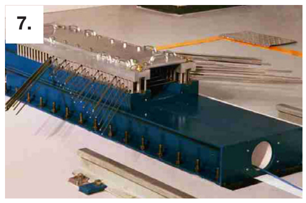
System performance can best be illustrated by comparison with the reverse acceleration pin-orifice (Hyge) sleds in use worldwide. Both systems mechanically shape the impact pulse as a function of the sled stroke, so both respond best when the sled is moving quickly. This means that the best accuracy and frequency response of the wire decelerator occurs at the beginning of the pulse. This is ideal for regulatory aerospace crash testing, as the beginning of the pulse is more tightly defined and is also most important for safety, as critical occupant and restraint loading is established early in the pulse. The system frequency response is very good and eas-

Table 1: Sled category, design and performance summary

	DECELERATION			ACCELERATION	
	Wire	Hydraulic brake	Servo-hydraulic	Pin-orifice	Servo-hydraulic
Pulse shaping	Better	Good	Better	Good	Best
Double pulse capable	Yes	No	Limited	No	Limited
Pre-braking capable & offered	Yes	No	No	No	No
Acquisition cost	1X	1X	2X	3X to 4X	3X to 9X
High Pressure operator	No	No	No	Yes	Yes
Maintenance cost	Low	Low	Moderate	Moderate	High
Time to generate new pulse	Best	Good	Better	Poor	Better
Pre-impact dummy movement	Minimal*	Minimal*	Minimal*	None	None

*Varies widely with manufacturer. Well-designed systems have negligible movement

THE BEST ASSURANCE FOR A SMOOTH TRANSITION INTO SLED OWNERSHIP IS A COMPLETE INTEGRATED FACILITY DESIGNED AND OPTIMIZED SPECIFICALLY FOR THE AVIATION INDUSTRY


6. Sled with rotatable top plate
7. Decelerator
8. Sled ballast

ily generates the basic triangular or trapezoidal pulses regulated for military and civilian aircraft applications as well as the other FMVSS and EC pulse profiles.

The most remarkable advantage is pulse predictability and accuracy, which is far better than with Hyge. The system's simulation program provides an easy user interface for inputting the desired pulse, velocity and wire pattern. From this information the program displays an accurate prediction of the resulting pulse.

Figure 1 shows in red the predicted pulse shape produced by the simulation, plotted with the actual acquired sled accelerometer data of three separate tests. The unsurpassed level of accuracy and repeatability shown in the graph is an everyday occurrence with the system. The typical level of accuracy and repeatability, from the prediction to acquired data, is typically ±2 percent through the initial 70 percent of the desired pulse.

Acceleration of the sled

The Seattle Safety sled incorporates a pneumatic piston accelerator producing a very accurate impact velocity that is predictable within ±0.4 percent and repeatable within ±0.2 percent. Since the principal disadvantage of decelerator sleds is pre-impact dummy movement, gentle sled acceleration is also of paramount importance. The system generates an approximate square wave acceleration, which as a matter of physics allows the lowest possible peak pre-impact acceleration. A typical acceleration profile for a sled impact velocity of 48kph (44ft/s) is shown in Figure 2.

The acceleration starts at about 0.43g, tapering to 0.32g just before the 0g coast, which is followed by the impact. To demonstrate the effectiveness of this approach, a 50th percentile male ATD was seated upright on an aircraft passenger seat and restrained with only a lap belt. The head was instrumented for displacement in the direction of inertial load, and movement was measured during the sled acceleration and coast phase.

The results shown in Figure 3 indicate that the head moves about 11mm (0.45in) during the acceleration and returns to its initial position ±2mm (±0.07in) during the coast period. The position of the head at impact was virtually unchanged from the original position prior to the run.

Dynamic capacity

One advantage of this decelerator system is the very high dynamic capacity and actual peak force obtainable by the system. Many competing systems cannot maintain rated peak force throughout their stroke length and experience a 20 percent to 60 percent drop from rated force. In contrast, the wire decelerator sled can achieve its full rated force of 1,000kN (225,000lb) throughout the entire test. Figure 4 gives a comprehensive look at the capability of the system.

Summary

Seattle Safety has become the dominant supplier of aerospace sled systems by delivering excellent performance at a practical cost. The system's ease of use allows greater flexibility in the choice of operating personnel, and the proven design is efficient and flexible as demonstrated by its time-saving features. It is available in a range of size capacities and other customer-selectable options to meet specific needs.

Developing the internal capability for conducting dynamic tests provides greater flexibility and control over the design and production process, although the decision to acquire these benefits comes with the uncertainties associated with costs and operation.

The best assurance to ensure a smooth transition into sled ownership is the complete integrated facility designed and optimized by Seattle Safety specifically for the aviation industry. It solves the conundrum of ownership economics versus outsourced services and ultimately frees manufacturers to do what they do best – produce quality products. This change to a focus on their item at test, rather than their actual ability to test, is a model certain to generate success.

Tom Wittmann is president at Seattle Safety, based in Kent, Washington, USA