

CID-720 AIRCRAFT
LaRC PREFLIGHT HARDWARE TESTS:
DEVELOPMENT, FLIGHT ACCEPTANCE AND QUALIFICATION

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INTRODUCTION

This paper addresses the testing conducted on LaRC-developed hardware for the CID-720 aircraft. It is divided into four major sections that first focus on the major test articles and the test environment. Other sections discuss the flight acceptance tests (FAT) and qualification tests, the fuselage vertical drop tests, and the heat shield development tests that were all performed in the LaRC test facilities.

LaRC - preflight hardware tests: Development, flight acceptance and qualification

- Section A
 - Major test articles
 - Test environments
- Section B
 - Major test units, FAT/qualification tests
- Section C
 - Fuselage vertical drop tests
- Section D
 - Heat shield development

MAJOR TESTING TASK

To properly develop flight qualified crash systems, two environments were considered: - the aircraft flight environment with the focus on vibration and temperature effects, and the crash environment with the long pulse shock effects. Also with the large quantity of fuel in the wing tanks the possibility of fire was considered to be a threat to data retrieval and thus fire tests were included in the development test process.

Develop flight qualified crashworthy systems

Consider

- Flight environment
 - Vibration
 - Temperature
- Crash environment
 - High shock
 - Possible fire

MAJOR TEST ARTICLES

The test articles included the primary pallet subsystems of the Data Acquisition System (DAS #1 located forward in the aircraft and DAS #2 in the rear). Each DAS system included four separate subsystems as follows: main electronic pallet, recorder pallet, battery/diode pallet and R/F pallet. The photographic test units included the 4 power distribution pallets, 10 camera mounts with thermal box assemblies and 24 flood light assemblies.

The other numerous small flight units were rigorously tested at the component level and are not considered as major test articles for discussion in this paper.

- Data acquisition system #1 (located Fw'd. in A/C)
 - Main electronic pallet
 - Recorder pallet
 - Battery/diode pallet
 - R/F pallet
- Data acquisition system #2 (located rear in A/C)
 - Main electronic pallet
 - Recorder pallet
 - Battery/diode pallet
 - R/F pallet
- Photographic system
 - Power distribution pallets (4)
 - Flood light assemblies (24)
 - Camera mount/box assembly (10)

FLIGHT ENVIRONMENT

The temperature testing was divided into two phases; the operational and non-operational. The testing criteria for the operational flight phase was obtained from the "RTCA/CO-160A" document. The flight and qualification levels were combined in this case and the temperature test range was from +40°F to 120°F with a 4.0°F/minute temperature rate of change. For the nonoperational condition the temperature level was set at 160°F for a period of 30 minutes. This temperature was selected based on previous experience with inside fuselage temperatures on aircraft located on the hot lake bed at the NASA-DFRF Facility during the summer period.

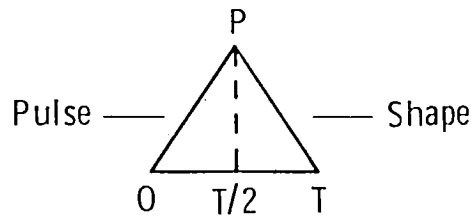
The test pulse simulating the crash environment had a triangular shape with a 100 msec duration. The flight assurance test levels are 17G for the longitudinal and normal axis, while the qualification levels are 25G peak. The above levels represent a long duration pulse profile expected from the crash of typical aircraft fuselage structures at vertical descent rates of approximately 20 ft./sec.

Temperature	Operational	Nonoperational
Combined qualification and flight	40°F to 120°F	160°F, 30 min

$$\nabla T = 4.0^\circ\text{F}/\text{min}$$

Crash environment

Shock

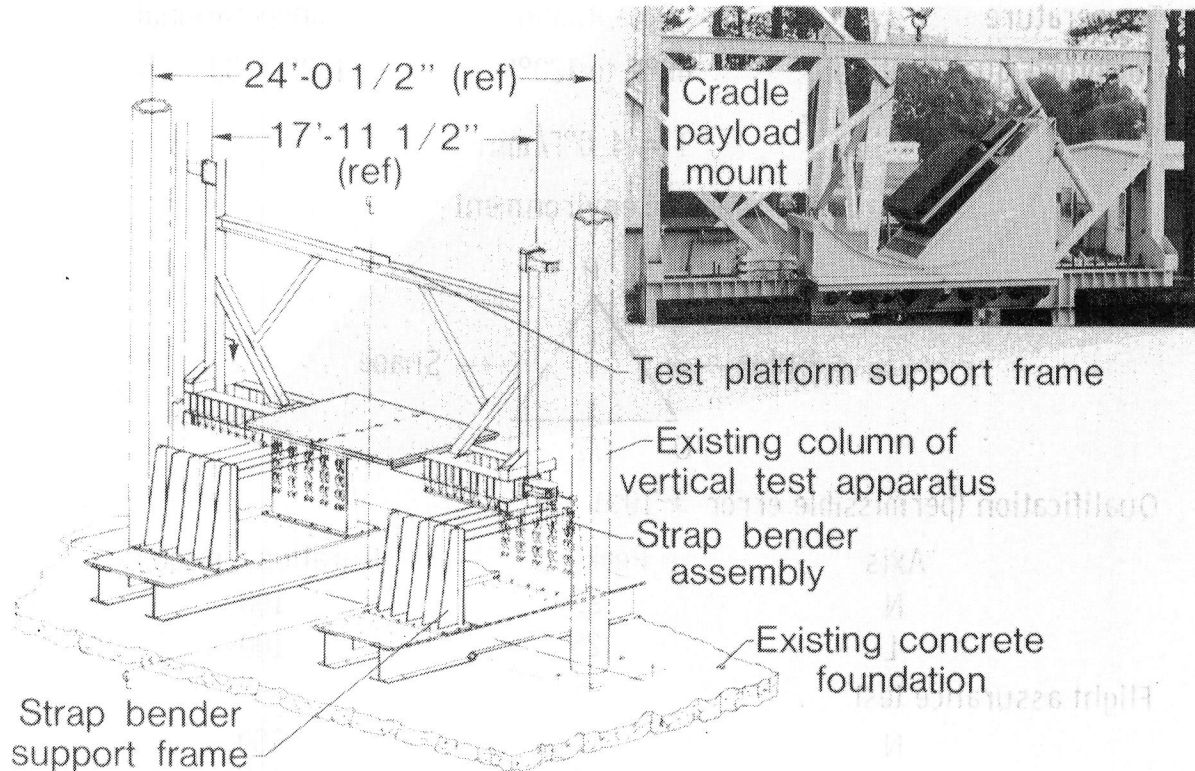


Qualification (permissible error $\pm 10\%$)

Axis	Peak, G	Duration, msec.
N	25	100
L	25	100
Flight assurance test		
N	17	100
L	17	100

PULSE GENERATOR SYSTEM
FOR VERTICAL DROP TOWER

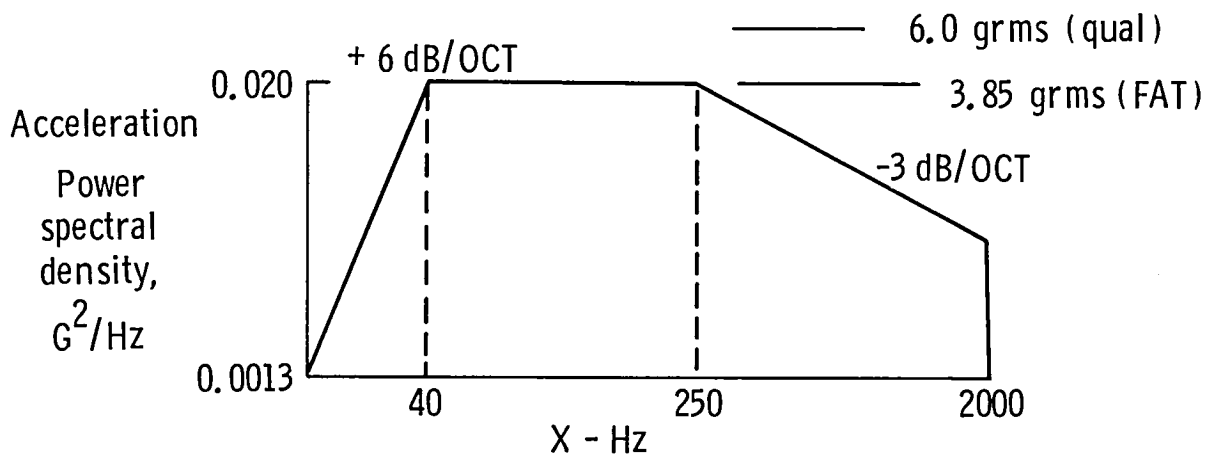
A special shock pulse generator system was installed in the LaRC 72 ft. high vertical drop tower facility. This system was designed for long duration shock pulse profiles and was ideally suited for shock qualification of the test articles. The key to this unique facility was the strap bender assembly. The technique was to extrude a wide (about 3 inches) stainless steel strap through offset rollers, thus absorbing considerable energy. A drop carriage guided on rollers impacted the selected number of straps from a calibrated drop height and total weight to give the desired pulse shape. The picture in the upper corner shows a rotatable cradle that was the interface mounting plane with the test article pallets. The cradle was positioned at 45 degrees to obtain the same shock magnitude for the normal and longitudinal axes. The payloads (test articles) in the picture depict the power distribution pallet and the 16 mm high speed camera surrounded with protective heat shield. These units were powered-up and operated successfully through the impact shock pulse.



FLIGHT ENVIRONMENT FOR AIRBORNE EQUIPMENT

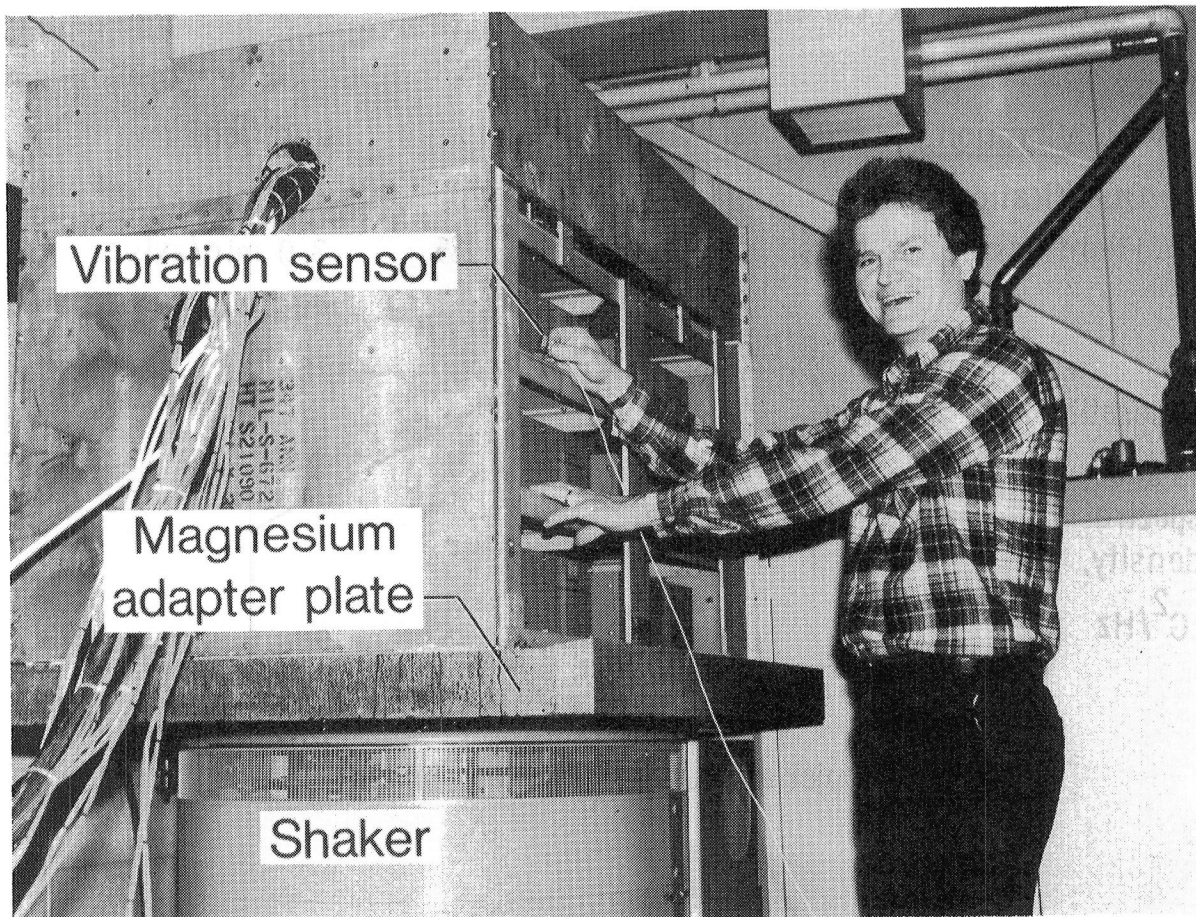
The testing criteria for turbojet aircraft fuselage mounted equipment were obtained from reference 1. The vibration profile of power spectral density (G^2/Hz) versus frequency (CPS) is plotted for flight assurance (FAT) and qualification tests. The maximum level for FAT is 3.85 grms (between 40 and 250 cycles) and for qualification is 6.00 grms. The period of vibration for each axis is 3.0 minutes for FAT and 4.5 minutes for qualification. Each major test article was tested in each of the three principle axes (normal, longitudinal and transverse). The vibration test frequency range is from 0 to 2,000 cycles per second (CPS) with a high sweep rate of 6 decibels (dB) per octave from 0 to 40 (CPS). The above vibration profile was input to each major test article bolted to adapter fixtures that approximated the aircraft tie-down technique.

<u>Vibration:</u>	<u>Axis</u>	<u>G (RMS)</u>	<u>Duration, min</u>
Qualification tests	N, L, T	6.0	4.5 min/axis
Flight assurance tests	N, L, T	3.85	3.0 min/axis



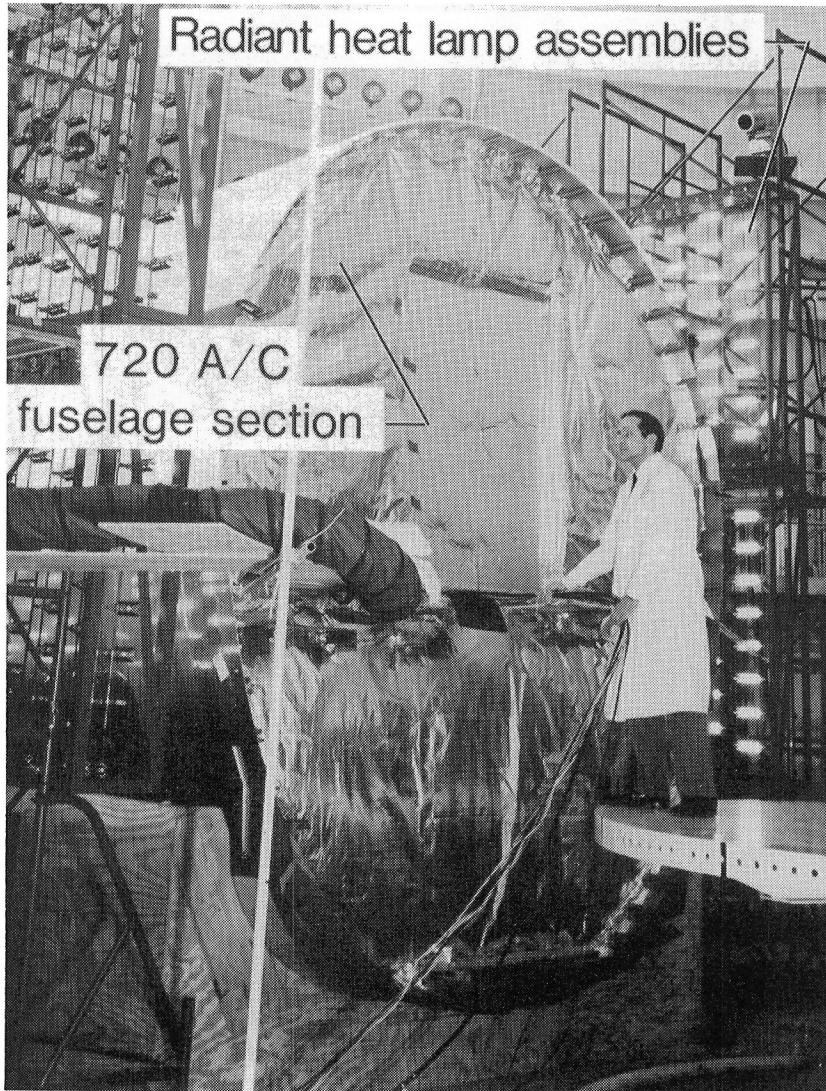
VIBRATION TEST
DAS - MAIN ELECTRONIC PALLET

The vibration test profile was input to the test article, mounted to a damped 4 inch thick magnesium adapter plate. The 17,000 force-pound shaker is shown in the vertical position with the adapter plate and approximately 900 pound DAS main electronic pallet mounted. The technician is shown placing accelerometers on each of the four shelves of the pallet unit, which has one heat shield side cover removed. The shaker was rotated 90 degrees and attached to a large slippery table for vibration of the longitudinal and transverse axes. The multicable harness was attached to the pallet components and the system was under power during the complete vibration test series. No major resonance conditions or abnormalities were evidenced during this test series.



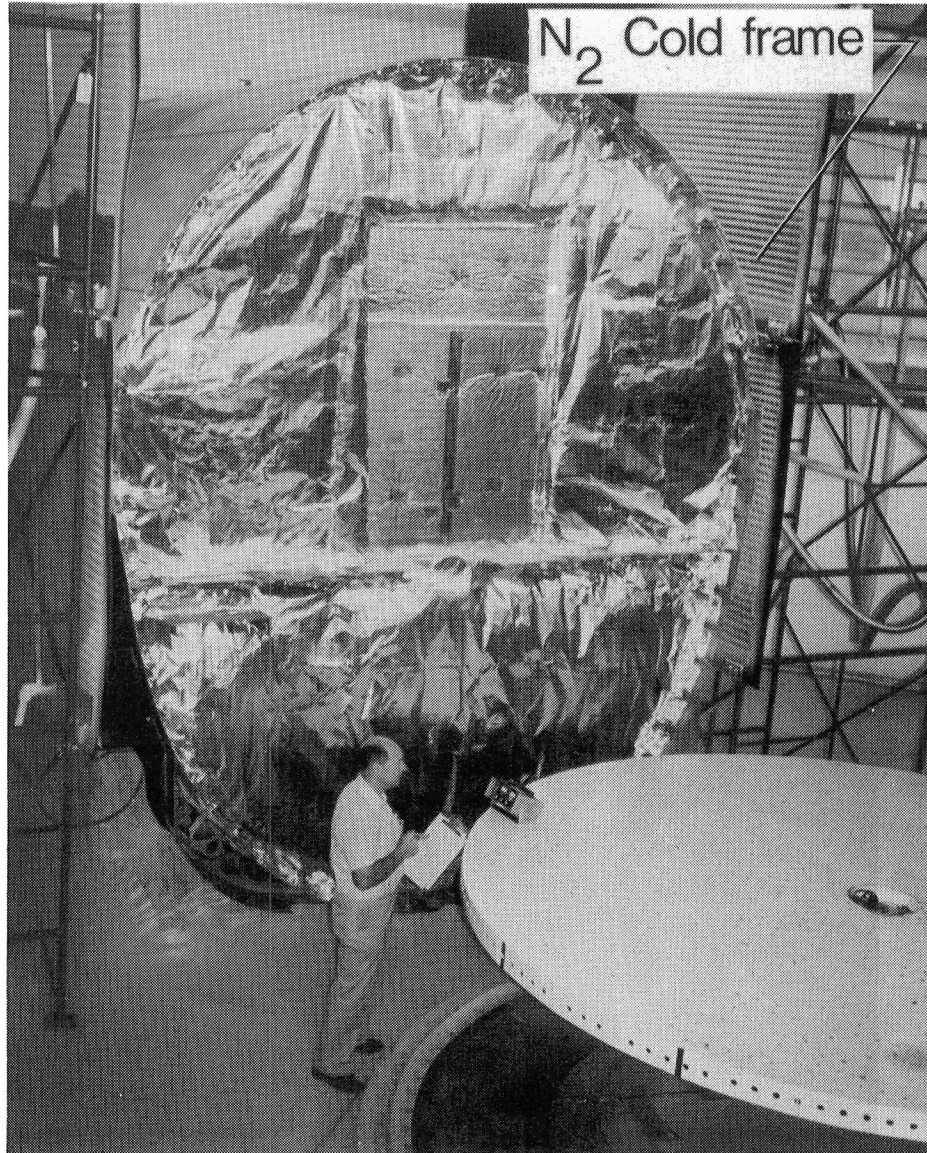
THERMAL (HOT) TEST

A full-size B-720 fuselage section was installed in the LaRC 55 ft diameter thermal vacuum facility and both ends of the section were thermally insulated. The test articles were placed inside in a typical location of the actual CID test aircraft. Large radiant heat lamp assemblies with quartz lights were positioned close to the fuselage section and powered until the inside fuselage temperature reached the desired level. All the test articles were operational through the high temperature test environment. For the nonoperational thermal (160°F) condition no power was supplied to the test units.



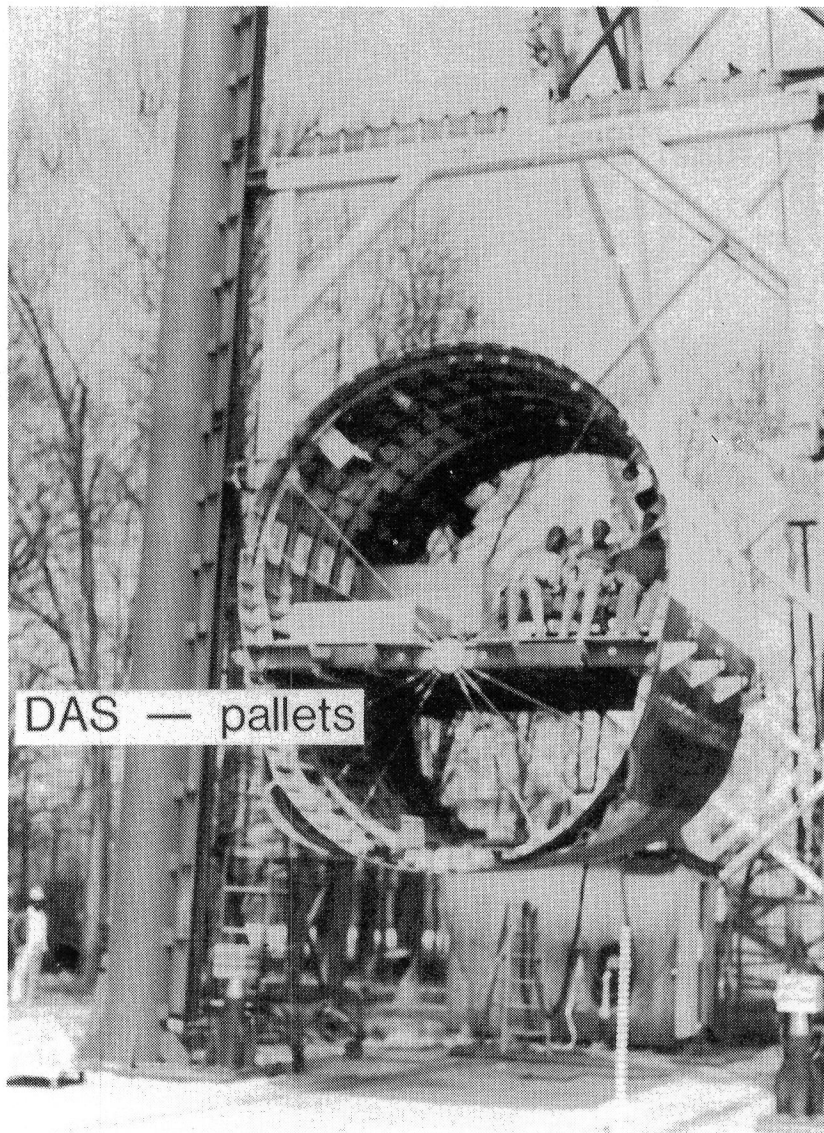
THERMAL (COLD) TEST

The full-size B-720 fuselage section was also used for the thermal (cold) test in the thermal vacuum facility. Large nitrogen cold frames were positioned adjacent to the fuselage section and temperature inside the fuselage was chilled by radiating heat away from the fuselage section to the cold frames. All of the test articles were operational through the cold temperature test environment. No major discrepancies or failures were detected throughout the thermal testing.



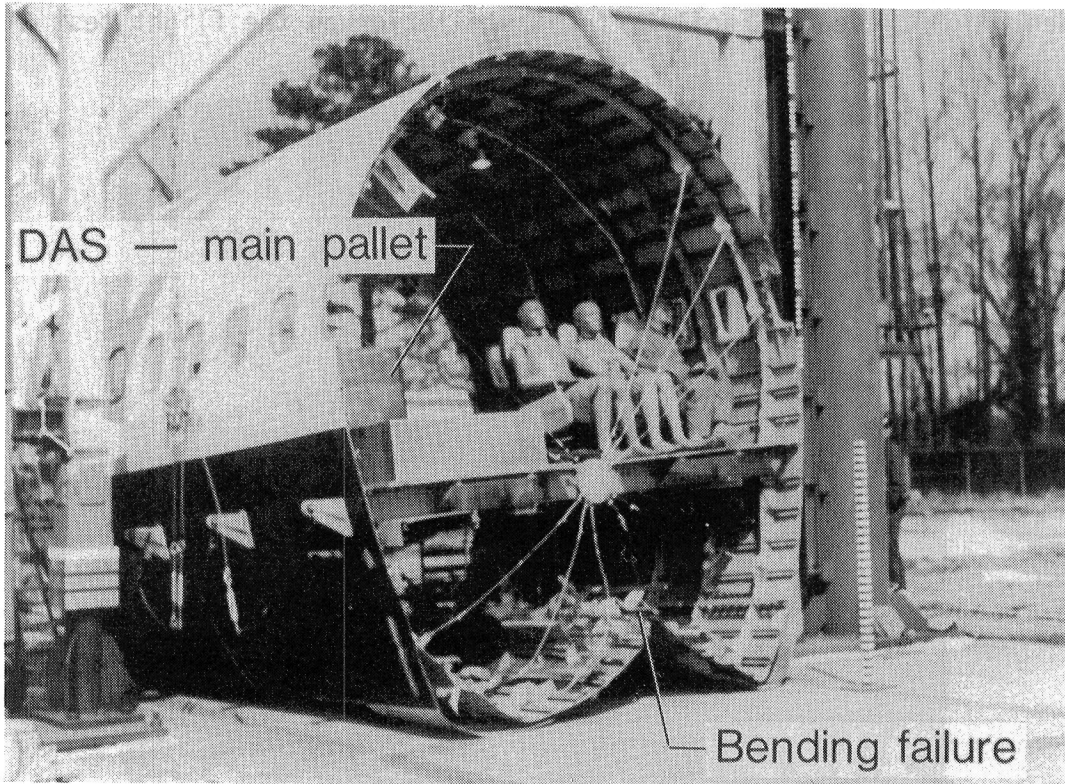
720 FUSELAGE (AFTERBODY) DROP TEST
FLIGHT SYSTEMS OPERATIONAL: QUALIFICATION

Actual fuselage sections (about 12 ft. in length) cut from a B-720 aircraft were mounted in the LaRC dynamic drop test facility for vertical drop tests. This picture shows the afterbody section (near the expected aircraft contact point) raised about 6 ft. above the concrete impact pad while being hung from the drop carriage fixture. This test unit was used to qualify the major test articles when integrated with the aircraft structure. All units were operational and data signals were telemetered at the 20 ft./sec. impact velocity. All systems performed as planned and this test was the final qualification prior to hardware shipment to NASA Dryden Flight Research Facility for installation on the flight test aircraft.



720 FUSELAGE (AFTERBODY) DROP TEST SHELL FAILURE
FLIGHT SYSTEMS OPERATIONAL

At impact, the lower fuselage shell failed where keel formers sheared and local bending occurred. A secondary bending and buckling occurred along the cargo shell sidewall. These structural failures absorbed considerable impact energy and contributed to reduced shock levels along the floor line where seats and pallets are mounted. All units were inspected after this test and shown to be qualified for flight test service.



CID-720 AIRCRAFT-FUSELAGE
VERTICAL DROP TESTS - COMPARISON

Three B-720 fuselage sections were tested in the LaRC vertical drop test facility. A comparison of the accelerometer levels at the 20 ft./sec. impact velocity is shown in this table. The three test articles were taken from the forebody, centerbody, and afterbody regions of the B-720 aircraft. The acceleration levels shown are approximate maximums during the impact duration. Note that the centerbody section had very much higher levels than the other sections because it was structurally very stiff and had little structural deformation or crush at impact. The forebody and afterbody sections compared closely, especially in the levels that the dummy pelvis sustained. There was a significant structural crush (about 18 inches) in the keel/cargo bay region of these sections, which reduced the shock input to the seats and dummy passengers.

$V_{\text{impact}} = 20 \text{ ft/sec}$

Acceleration levels

(at contact) @ 60 Hz filter

Item	Fuselage section #1 (forebody)	Fuselage section #2 (centerbody)	Fuselage section #3 (afterbody)
Fuselage keel	22	High	60-100
Side frame/floor beam	10 to 12	95	10-15
Floor @ seat rails	9	70	15
Dummy pelvis	9.0	40-60	9.0-12.0
Crown	10-20	100	10

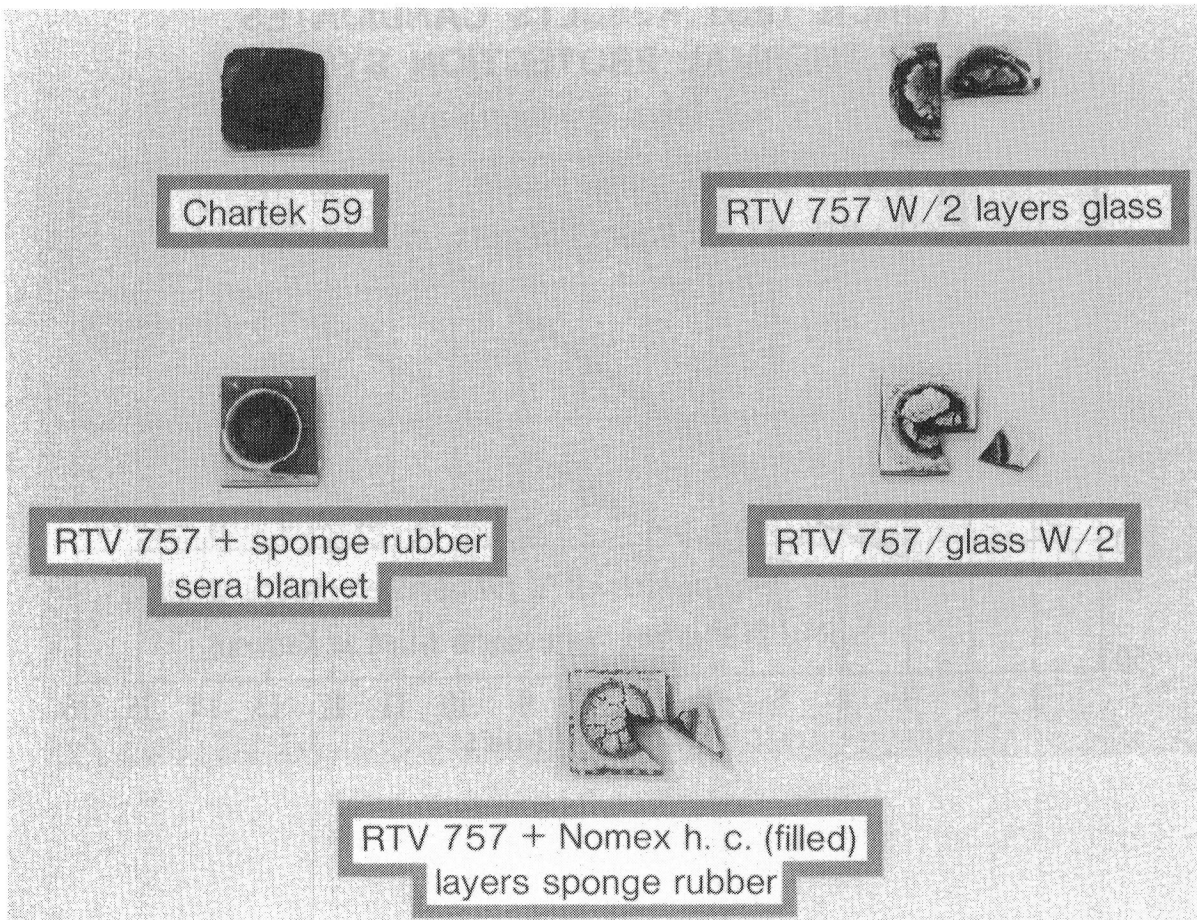
TASK

Since the CID-720 flight test aircraft carried a large quantity (about 11,000 gallons) of jet fuel in its wing tanks, a decision was made at LaRC to proceed with a protective shield development task. This development of crashworthy thermal protection shields was to provide protection for eight (8) data acquisition pallets, ten (10) photo cameras, and four (4) camera/lights power distribution pallets. The design goal was to survive an intense fuel fire for 10 minutes duration (an estimate of the minimum time to reduce an aircraft fuel fire). Also, another design goal was to survive large structural debris flying through the cabin during the crash slide-out phase.

- Development of crashworthy thermal protection shields
 - Data acquisition systems (8)
 - Photo cameras (10)
 - Camera/lights power distribution pallets (4)
- Goals
 - Survive intense fuel fire, 10 min. duration
 - Survive flying debris during crash slide-out

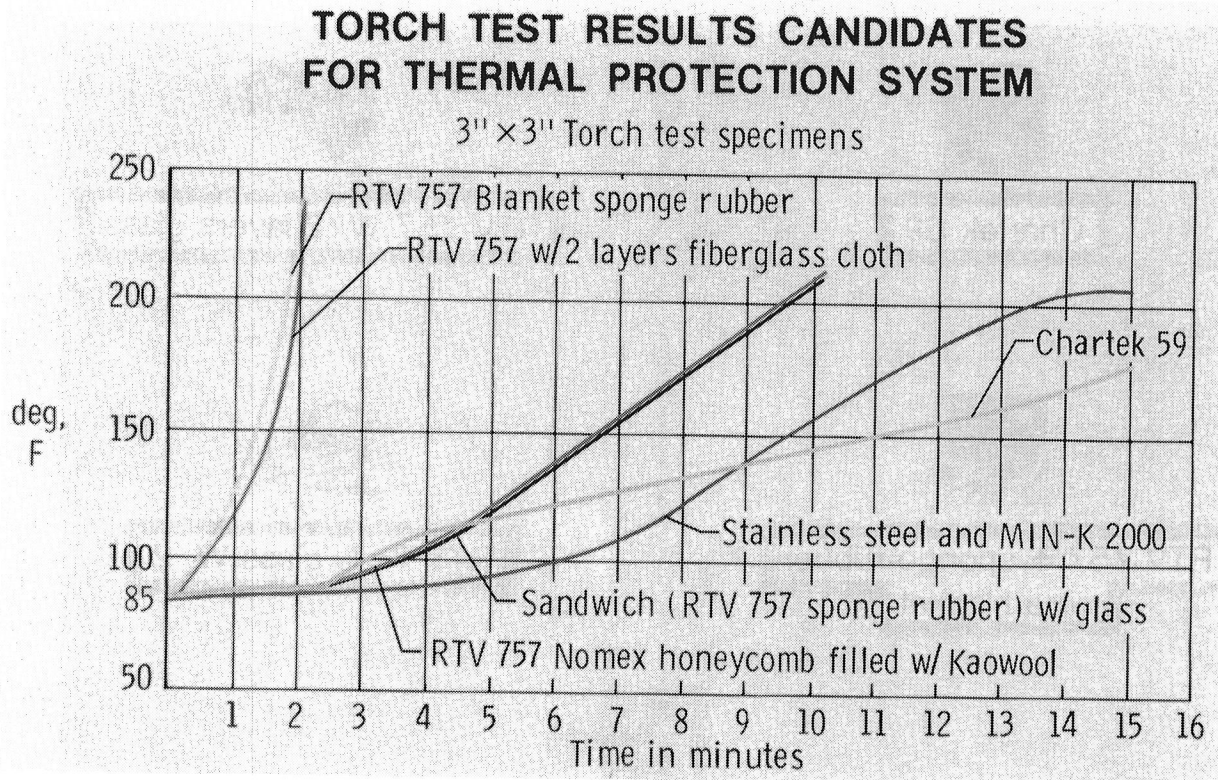
CANDIDATE FIRE PROTECTION SAMPLES
3" SQUARE TORCH TEST SPECIMEN

A screening test program of 3" square candidate fuel fire resistant samples was initiated. The five (5) samples shown in this chart represent the best combination of heat resistant materials from the total screening program. Each test sample was mounted in a ceramic holder while an acetylene torch was applied on one surface (face down) and a thermocouple/recorder showed the temperature increase with time on the back face of the sample. Another leading sample, stainless steel and MIN-K, is not shown in this chart.



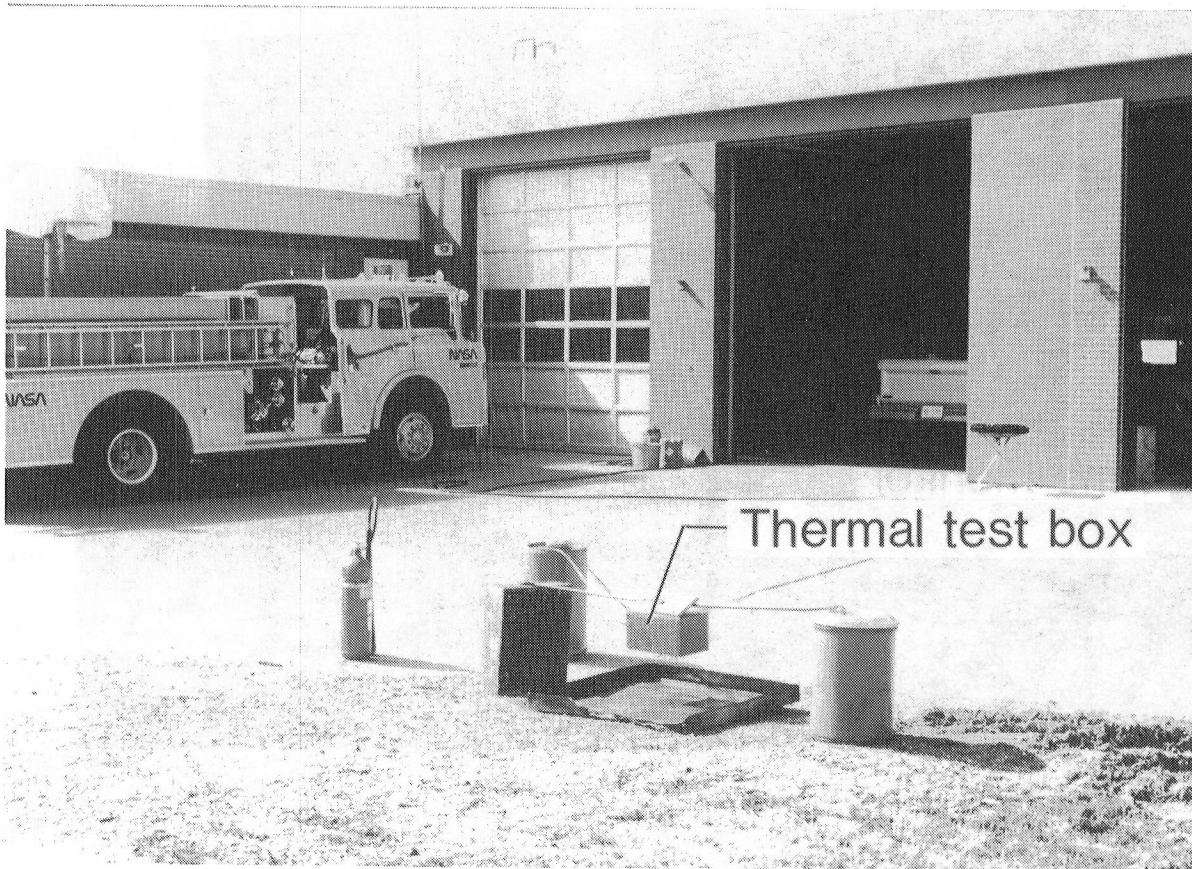
TORCH TEST RESULTS CANDIDATES
FOR THERMAL PROTECTION SYSTEM

This graph shows the thermal comparisons of each of the candidate torch test specimens. The back-face temperature (degrees fahrenheit) plotted against duration of applied heat (in minutes). It shows that for the 10 minute design duration, the chartek 59 and stainless steel with MIN-K 2000 were nearly equal, but for longer times the chartek was lower in temperature rise on the back face of the specimen.



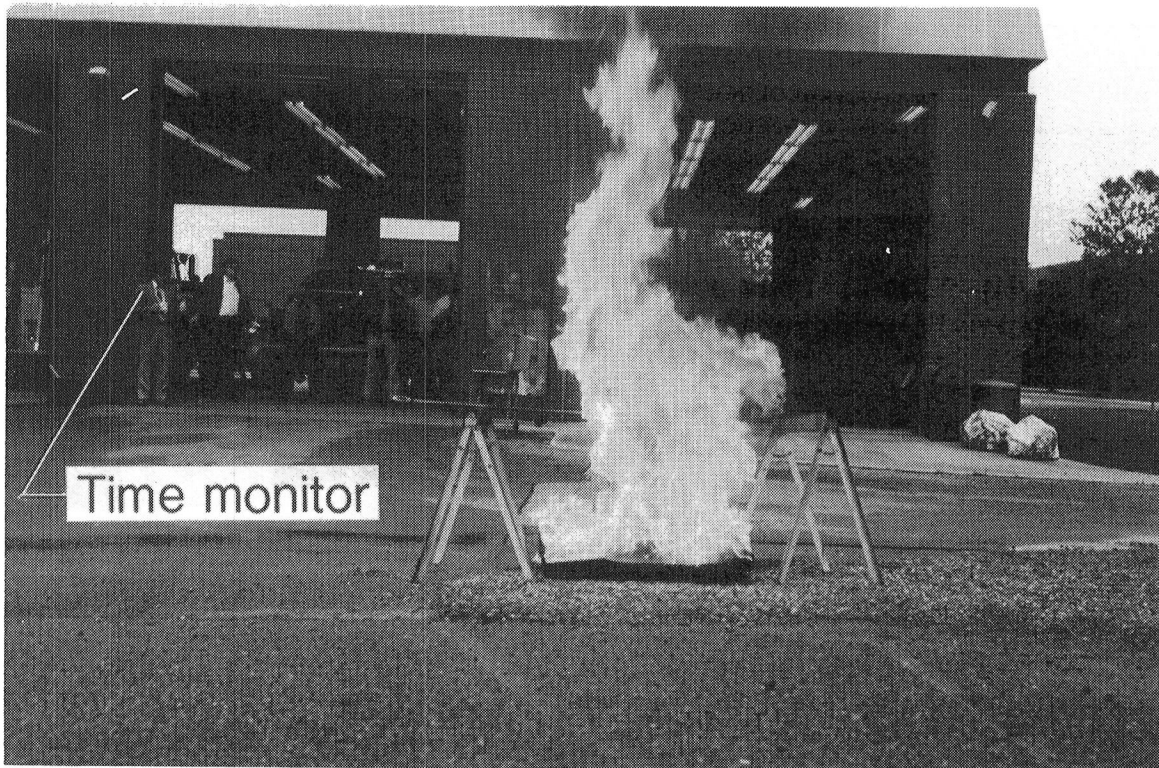
FIRE TEST SETUP

The next phase of the thermal shield development was to conduct an actual fuel-fire test with a fabricated heat shield from the best candidates of the torch screening tests. The LaRC fire department set up a quick (low budget) fire test using available equipment for an actual 10 minute gasoline fire in an uncontrolled environment. The thermal test shield was fabricated around a dummy camera and suspended by a steel rod. A large square fry pan was filled with approximately 5 gallons of gasoline. All thermocouple leads were routed to a recorder located inside the walls of the fire station.



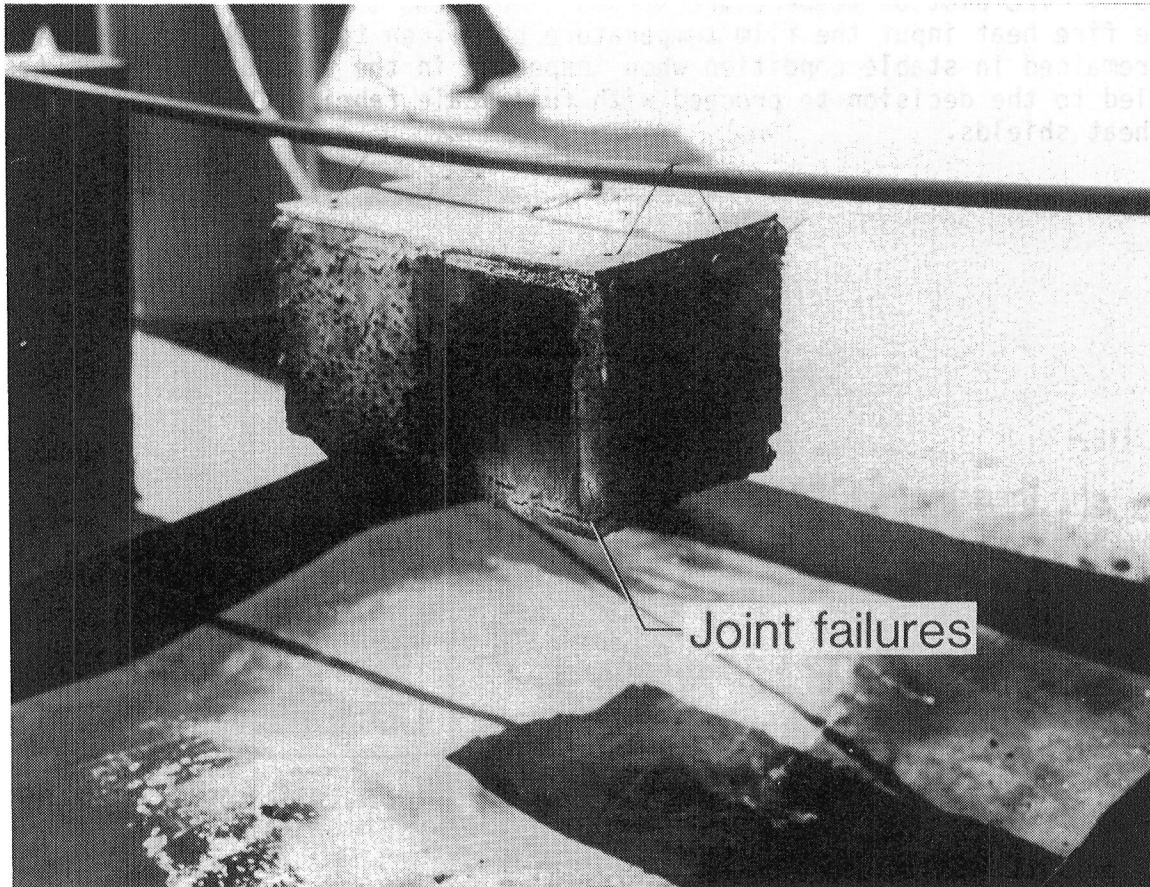
FIRE TEST - FLAME

A long handle torch was used to light the fire that enveloped the test unit for the ten (10) minute test period. The environment was uncontrolled but an attempt was made to select test periods with low wind velocity. The inside camera box temperatures were monitored with four (4) thermocouples located at critical areas. The temperature rise was indicated on a constant speed strip recorder and a backup time monitor was selected to determine the effective fire input duration.



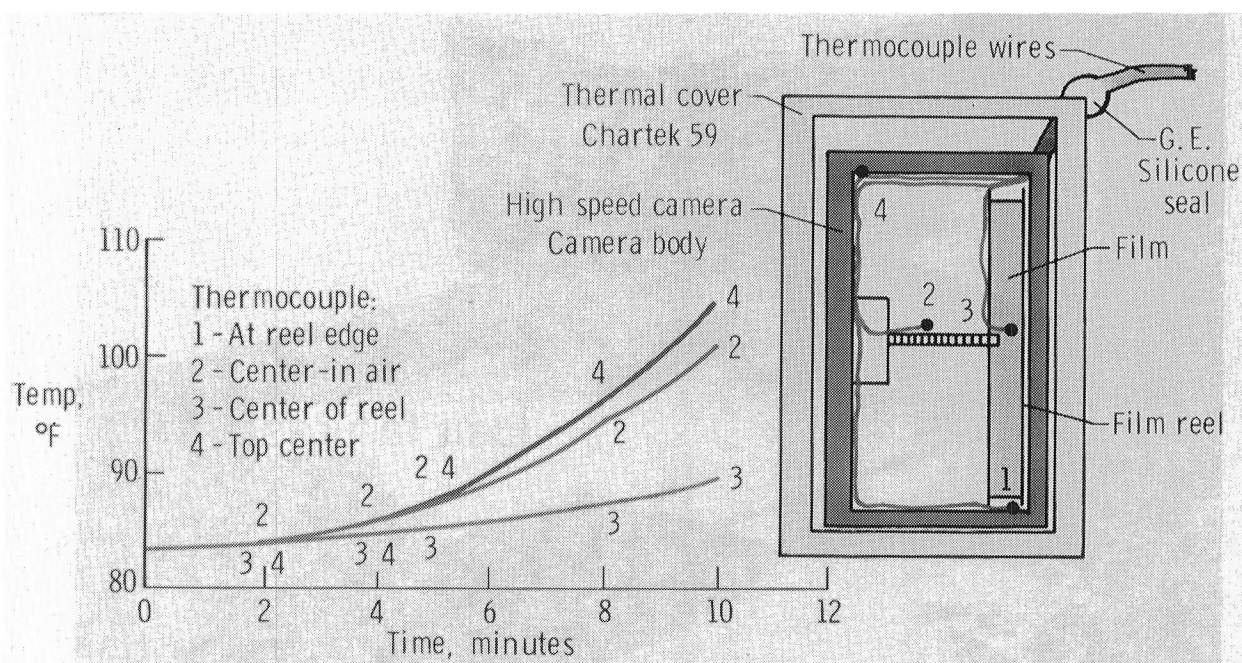
FIRE TEST - RESULTS

This initial fire test was not successful since the heat shield joints at the box corners opened and the flame entered to the metal dummy camera. All the inside thermocouples rapidly increased in only several minutes. The resulting temperatures would have destroyed any film inside the camera body.



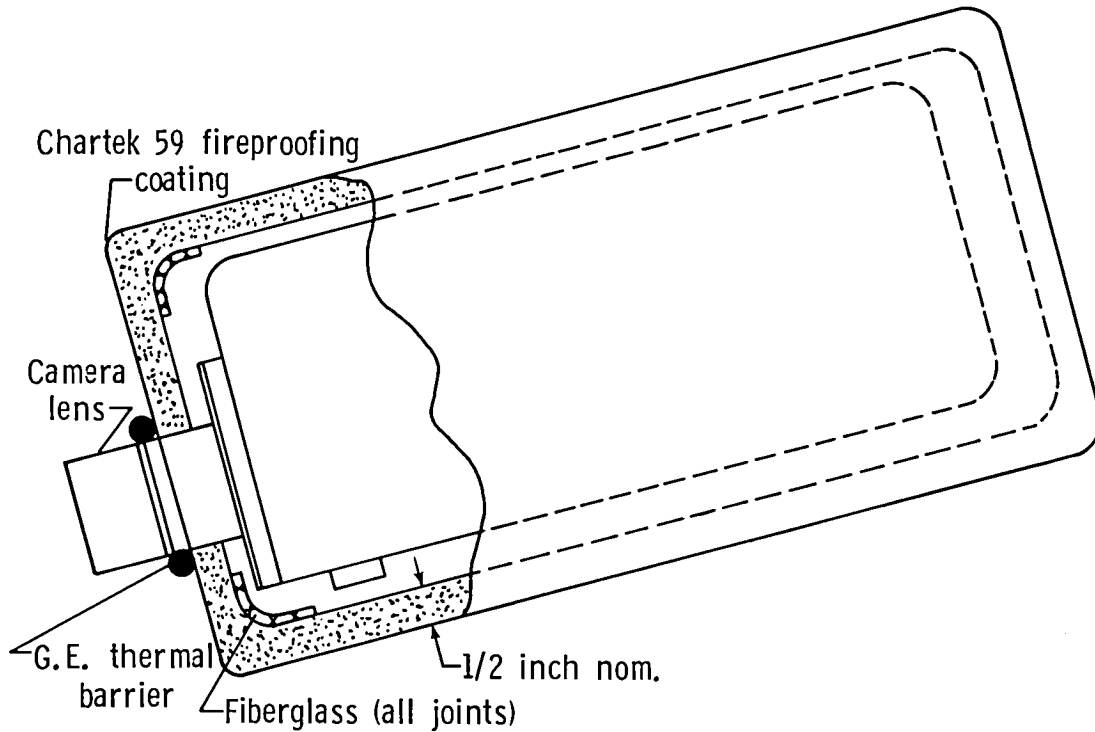
THERMAL PROTECTION

This figure shows a sketch of the last successful fire test using a chartek 59 thermal cover with fiberglass reinforced corners. The inside of the camera body included a 100 foot roll of 16 mm film that had been exposed under laboratory conditions. Thermocouple #3 was located on the film and the leads were routed out the corner of the box and sealed with a special General Electric high temperature silicone resin. The plot of temperature versus time shows that after 10 minutes gasoline fire heat input the film temperature had risen to only 90°F. The film images remained in stable condition when inspected in the laboratory. This test result led to the decision to proceed with full scale fabrication of the actual flight heat shields.



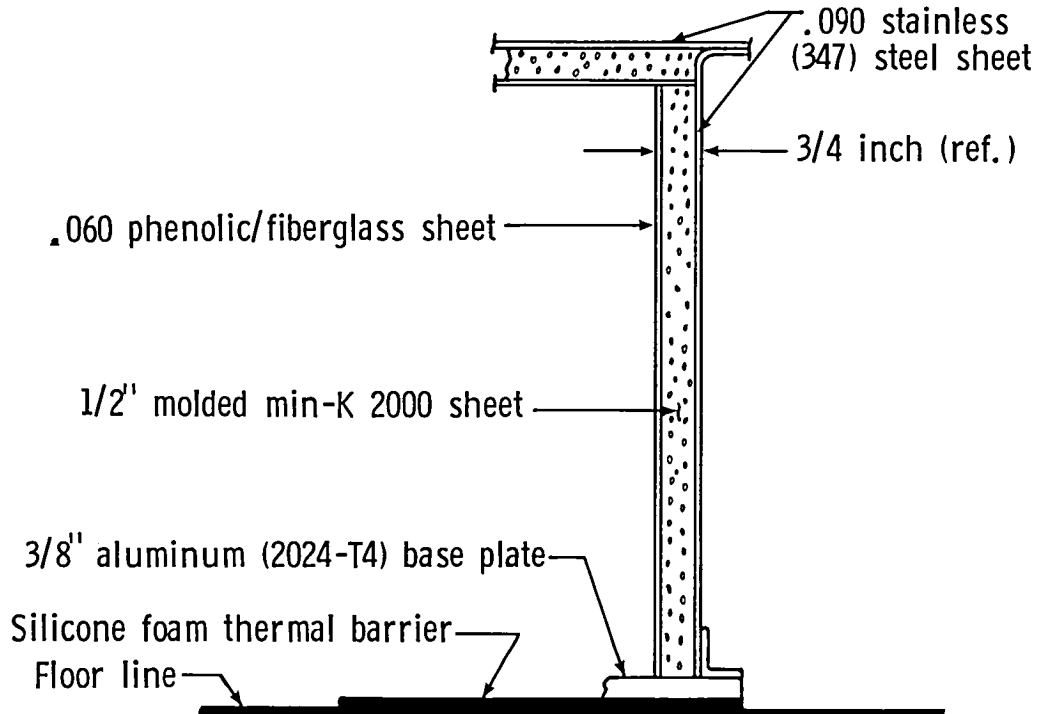
CAMERA HEAT SHIELD

This sketch shows a cutaway view of the chartek 59 fire proofing heat shield and the high speed 16 mm camera and lens. Notice the fiberglass reinforcing at the joints and the General Electric thermal barrier used to seal the port through the shield for the lens. A similar design was used at the rear of the camera where an electrical plug protruded through the heat shield. This was the fabrication technique used on the ten (10) high speed cameras mounted inside the fuselage.



DAS-RECORDER HEAT SHIELD

This sketch shows the fabrication technique for the data acquisition system-recorder heat shield. There was a 3/4 inch sandwich wall of .090 stainless steel sheet on the outside and .060 phenolic fiberglass sheet on the inside. Between the face sheets was a 1/2 inch thick molded MIN-K 2000 sheet material. The walls were attached at the 3/8 inch aluminum base plate with a sheet of foam silicone thermal barrier used to seal to the floor line of the aircraft.



SUMMARY FINDINGS FROM FIRE DEVELOPMENT TESTS

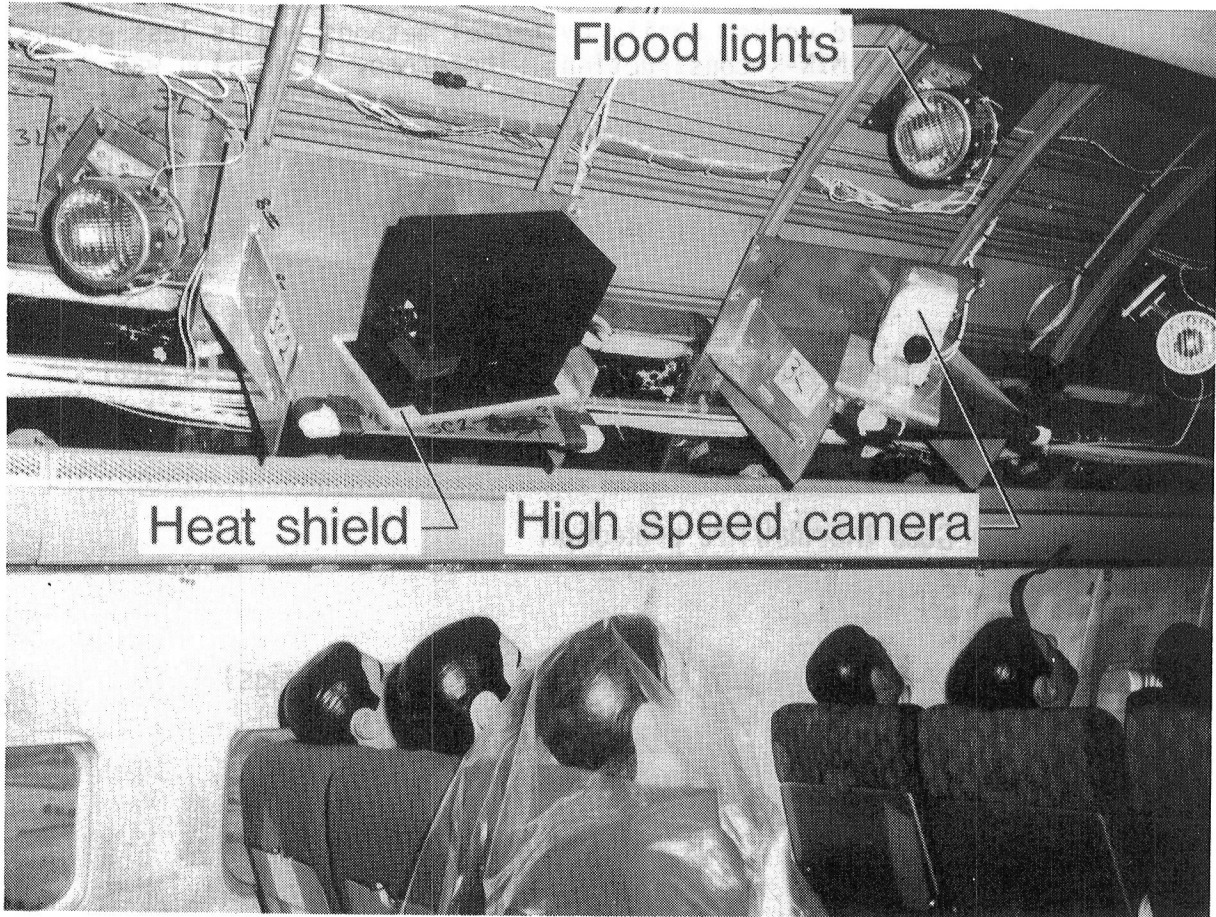
Two protective shield concepts were selected for the LaRC developed hardware systems. The first construction technique consisted of .090 stainless steel-MIN-K 2000-phenolic fiberglass. This type of construction is similar to some advanced aircraft flight recorders with excellent penetration protection as well as good thermal/fire protection. Unfortunately, this type of construction is expensive in terms of labor and material cost. The other construction technique using the chartek 59 material had the best thermal results in the LaRC ground fire tests. Also, it is a proven fire retardant in common oil company usage (on oil rigs). This material can be handled and worked easily by trowel methods and is less expensive than the stainless steel MIN-K construction. Therefore, a decision was made to use chartek on all the photographic system units and on the DAS battery and tele-meter pallets. These did not contain expensive electronic components. The main DAS electronic pallet and recorder pallet used the more reliable flight recorder construction concept (stainless steel and MIN-K-2000) since these units had to survive for longer periods and hopefully be returned to LaRC for use in other programs.

- Advanced flight recorder construction technique (stainless steel-MIN-K2000-Phenolic fiberglass)
 - Good penetration protection
 - Good thermal/fire protection
 - Expensive

- CHARTEX 59 - proven in oil company usage (on oil rigs)
 - Best thermal results in LaRC test
 - Less expensive

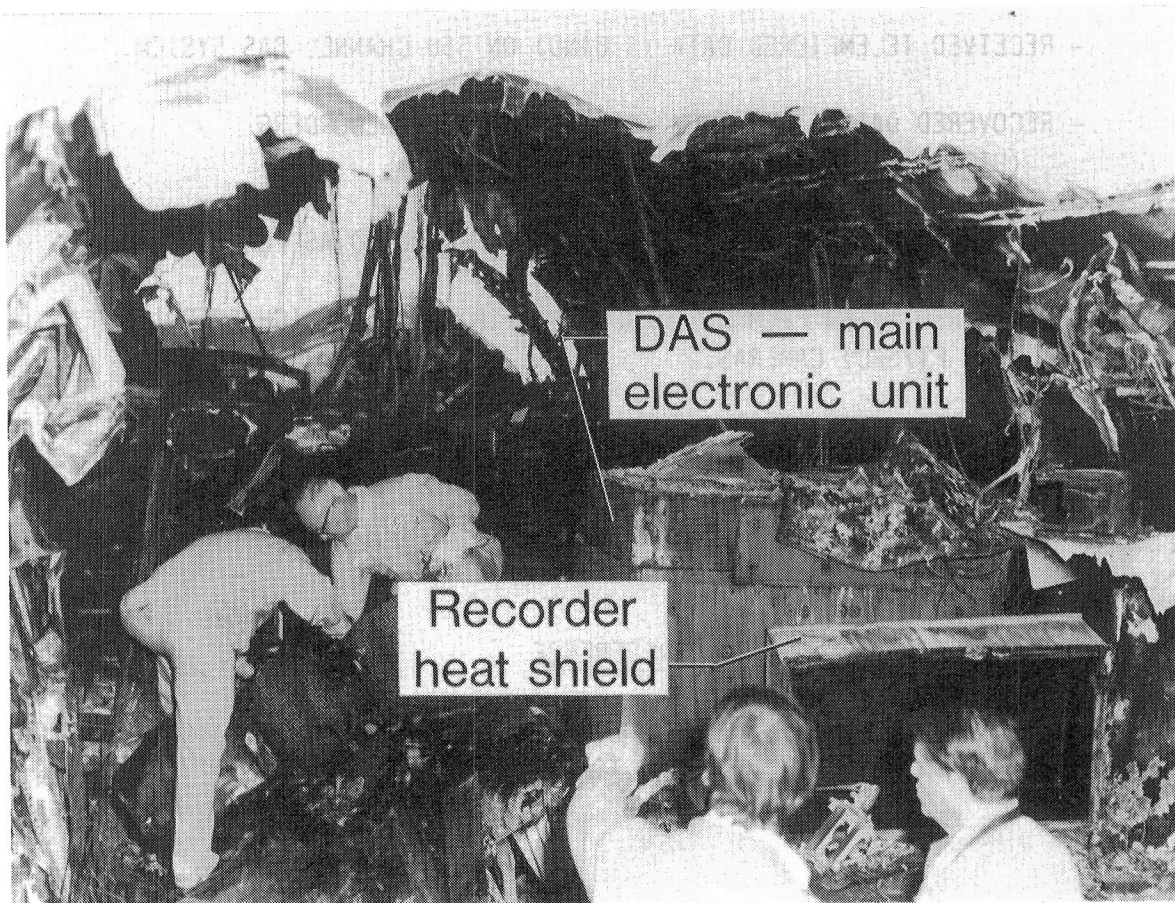
CAMERA HEAT SHIELD - INSTALLATION

This photo of the internal fuselage shows the high speed camera/ mounts attached to the fuselage crown frames. Also shown are the high intensity floor lights and the dummy passengers/seats. The most rear facing camera is enclosed in the chartek 59 heat protection shield; notice the lens protruding through the box without the doughnut shaped silicone seal ring installed. The other 16 mm camera is shown mounted atop a chartek 59 insulator plate before the heat shield enclosure has been attached.



CID-720 POST-FIRE REMAINS

This photo shows the remains of the CID-720 test aircraft after the crash test with the subsequent intense fire. This is a view inside the fuselage looking forward. Shown standing rigidly in place is the DAS-main electronic unit with heat shields in place and molten aluminum metal deposited on its top from the melt down of the aircraft crown section. The DAS recorder heat shield is shown on its side after removal of the data tape from the recorder package. Both the heat shield and the data tape were in good condition. In the far right side of the photo can be seen a camera heat shield on its supporting aluminum mounting (partially melted) after removal of the 16 mm high speed camera and its spool of good film. The two technicians on the left side are inspecting the large chartek 59 heat shield that was still in excellent condition (less than 1/8 inch char layer) and the photographic power distribution system inside had performed its mission flawlessly.



SUMMARY

The CID-720 aircraft test successfully demonstrated the performance of the LaRC developed heat shields. Good telemetered data (S-band) was received during the impact and slide-out phase, and even after the aircraft came to rest. The two onboard DAS tape recorders were protected from the intense fire and high quality tape data was recovered. The complete photographic system performed as planned throughout the 40.0 sec of film supply. The four photo power distribution pallets remained in good condition and all ten onboard 16 mm high speed (400 frames/sec) cameras produced good film data.

SUCCESSFULLY DEMONSTRATED PERFORMANCE OF LARC DESIGNED HEAT SHIELDS

- RECEIVED TELEMETERED DATA (S-BAND) ON 350 CHANNEL DAS SYSTEM.
- RECOVERED DATA TAPES FROM (2) ONBOARD TAPE RECORDERS
(HIGH QUALITY DATA)
- ALL PHOTO POWER DISTRIBUTION PALLETS PERFORMED AS PLANNED.
- RECOVERED 16 MM FILM DATA FROM ALL (10) ONBOARD HIGH SPEED
(400 FT/SEC) CAMERAS.

REFERENCE

1. Environmental Conditions and Test Procedures for Airborne Equipment. RTCA/DO-160A, Radio Technical Commission for Aeronautics, Washington, DC, Jan. 1980.

QUESTIONS AND ANSWERS

PRESENTATION BY ROBERT J. HAYDUK: "CID OVERVIEW"

Q: Walt Overrand, Delta

I was surprised at the interior. What was the aim and purpose in not having a full interior with carpets and so forth?

A: Bob Hayduk, NASA Langley

I would like to direct that question to John Reed after I state that the structural loads experiment was primarily concerned with the airframe and the wings and pylon and that the seat experiments were next in interest to us. I don't believe we had a strong materials group that was interested in filling out the complete interior of the aircraft.

A: John Reed, FAA

Needless to say, we did not plan for a fire. It was not an objective. The fire safety experiments were installed later in the preparation of the test article. Since we did not plan a fire, the interior liners were not of interest to us, either the cargo liners or the interior cabin. So there just was not any attempt in the basic experiments, from the antimisting kerosene, the crashworthiness, and the fire safety, to concern ourselves with replicating today's typical aircraft interior.

Q: Ed Widmayer, Boeing

Are you going to release the accelerations for the entire slide out?

A: Bob Hayduk, NASA Langley

We plan to release all the data that we measured as soon as the analyses are complete. At this time we have a package of about 80 channels of data for the time period of specific interest to the structural loads experiment. We have the one second after the left wing impact, and the wing cutter impact occurred after that.

PRESENTATION BY RUSS BARBER: "CID FLIGHT/IMPACT"

Q: Speaker unknown

I'd like to know what the power was on touchdown and how the airplane got so far off line.

A: Russ Barber, NASA Dryden

The aircraft had a lateral deviation at about 200 feet in altitude. We had a project guideline that once the airplane went below 150 feet, the pilot was committed to impact. We had to do that in order to be able to activate both the on-board cameras and the cameras that were located out on the lakebed, as well as some of the other data systems. At 200 feet the airplane was slightly to the right

of the centerline, but the pilot thought he could get back. He committed at 150 feet and got rather vigorous on the controls attempting to get the airplane back, and that resulted in the trajectory you saw. The power setting at impact, as near as we can determine, can be represented by the following table.

Time	Engine no.	Engine pressure ratio	N ₂ *
09 22 10.980	1	1.1	76
	2	1.2	77
	3	1.2	77
	4	1.1	74

*N₂ = high-pressure compressor rotor speed in percent (97 percent = 9670 rpm = takeoff power).

Q: Speaker unknown

From your point of view, if you were going to do this over again what would you do differently?

A: Russ Barber, NASA Dryden

I would start out with an airplane that had a hydraulic control system so that we could have a redundant control capability, rather than a single string, which increased the pressure of making the impact at the earliest opportunity. I think we could make some improvements in the guidance we provided the pilot. These video guidance systems looked relatively good down to the 150-foot altitude that we were able to test them to. When you get to altitudes below that the gains get quite high on those systems, and we really weren't able to identify this on the simulator that we had developed to pre-analyze our capabilities.

Q: John Clark, NTSB

What data did you use to generate the numbers you presented for sink rate, velocity, and pitch and roll attitude?

A: Russ Barber, NASA Dryden

Theodolite data.

Q: John Clark, NTSB

Looking at the cameras?

A: Russ Barber, NASA Dryden

Yes.

Q: Dave Ramage, Air Canada

What effect did the fact that you didn't hit the ground in a wings-level attitude have on the load data you got from the airplane? Did it cause any problems or did you get what you wanted?

A: Bob Hayduk, NASA Langley

We got the data we desired in terms of numbers of channels, but the left wing impact and subsequent nose impact reduced the sink rate on the fuselage, which caused the overall load levels to be substantially lower than we anticipated. However, the results that we have are still going to permit us to accomplish our major objective of having a baseline of data that we can use to validate our computer program. The data is still going to provide us with the capability to achieve what we desired to achieve.

Q: Howard Asher, Cessna

What type of ground did the fuselage actually impact on the head of the rockbed - what were the actual soil conditions?

A: Russ Barber, NASA Dryden

The lakebed is a surface that is as dense as concrete. The surface layer is softer, so you will see dust, but you could essentially conclude that it hit a surface as hard as concrete.

PRESENTATION BY E. ALFARO-BOU:
"NASA EXPERIMENTS ON THE B-720 STRUCTURE AND SEATS"

Q: Gil Wittlin, Lockheed

For the pulses that you talked about in the dynamic tests, were those vertical accelerations?

A: E. Alfaro-Bou, NASA Langley

The pulse on the sled was vertical, and the pulse on the seat pan was at 45 degrees with respect to the ground.

Q: Gil Wittlin, Lockheed

What was the position of the accelerometer?

A: E. Alfaro-Bou, NASA Langley

It was normal to the wedge, which was 45 degrees to the ground.

Q: F. Clark, American Airlines

I didn't quite understand your answer; did you have a forward component of g?

A: E. Alfaro-Bou, NASA Langley

Yes, we had a forward, which we call longitudinal, and a normal component.

Q: F. Clark, American Airlines

What were the two vectors; how many g forward and how many g down?

A: E. Alfaro-Bou, NASA Langley

I only showed the normal component; the longitudinal would have been the same because it was at 45 degrees. On the seat pan, it was roughly 12 g's for both normal and longitudinal components.

Q: F. Clark, American Airlines

Comparing this to the actual crash, the forward g was very small compared to the down, so this was not the same simulation when you get down to it?

A: E. Alfaro-Bou, NASA Langley

No, that was no simulation; this dynamic test was a very hard test for the seat. We wanted to make sure that the seat would survive, and we were not expecting pulses of this kind in the crash impact demonstration. The dynamic test was mostly to make sure that none of the components, the seat legs or any part of the seats, would fail.

A: Bob Hayduk, NASA Langley

That was a developmental test for the seat. We had designed the seat to begin stroking with a vertical load of 10 to 12 g's, so we exceeded that level in our developmental tests and were expecting that kind of level at that location in the aircraft. We did not achieve that level, so consequently did not get the kind of stroking we were expecting out of the seat.

Q: Dick Chandler, CAMI

On the curve showing the deceleration on the drop tower tests, I interpret the carriage input pulse to be a vertically oriented accelerometer on the carriage and the seat pan pulse to be a normal 45 degree oriented accelerometer on the seat. Wouldn't that say that if this was all a rigid ideal non-energy-absorber system, the seat pan pulse should be about 7/10 of the vertical pulse or somewhere around 10 g's? In other words, did you really get energy absorption here?

A: E. Alfaro-Bou, NASA Langley

Actually, I had not looked at it that way. In this particular test all we were concerned with at the time was making sure that all the seat components would stay put on the CID, that nothing would break. We did have a bit of a problem in a way with the energy absorber. Even though we still have one more inch of absorption left, the material from the composite tube went inside the tube and it became solid. So we did have a solid impact in there,

and that's why I didn't say much in here about energy absorption because there was a flaw in the mechanism that allowed all this material to get out of the tube. Later on we made a bigger opening on the tube so that this would not happen, but we did not do another test. So, as far as the energy absorption is concerned, this would not give you a pulse indication of what the seat can actually do. The seat still needs to be fine tuned and we never did any other tests due to lack of time. After the last testing, we just refurbished the seat and packed it and sent it back to Dryden.

Q: Dick Chandler, CAMI

When you refer to seat pan pulse, as I recall the Airst 2000 seats have a fabric seat pan. Is this really a seat frame?

A: E. Alfaro-Bou, NASA Langley

The seat pan acceleration was actually measured on the rear tube, which was on the seat frame.

PRESENTATION BY E. L. FASANELLA:

"NASA SEAT EXPERIMENT AND OCCUPANT RESPONSES"

Comment: Dick Chandler, CAMI

The DRI model, of course, is a military model and it is a simple oscillator that you can apply to virtually any measurement that you choose to apply it to. But when you begin looking at DRI versus the military ejection seat experience, it's always prudent to see what was being measured when the DRI was calculated. There is a military standard that governs testing of ejection seats and ejection capsules, and the acceleration measurements used are chest accelerations and seat pan accelerations. If the truth were known, the dummies that were in use at the time the DRI model was originated didn't even have a pelvis, let alone a place to measure pelvis acceleration. So for a number of years, we at CAMI have been trying to somehow correlate pelvis DRI with seat pan DRI. In a recent set of tests we did in cooperation with the Air Force, we had the opportunity to do this in a very closely controlled military-type of seat and restraint system, and we found that the pelvis DRI was about 1.43 times the seat pan DRI. That is the basis for the Air Force injury curves you showed. Unfortunately, the standard deviation was 0.16, so if you want to look at a confidence interval you can say it's somewhere in between 1 and 2 times as high. Even more unfortunately, when we try and do it for less well-structured seat and restraint systems, the correlation is even poorer. So I really don't know what your pelvis DRI means in terms of injury, other than I suspect that it's considerably higher than would be an indication by a true seat pan initiated DRI measurement by probably at least a factor of 1.43.

A: Ed Fasanella, Kentron

Your comment is correct. As I mentioned here earlier, there's quite a bit of controversy about human tolerance criteria and you really have to use

them with due caution. I used this model primarily as a comparison tool, so I could compare the various occupants and give you some numbers. But there's always a lot of argument among the experts in the field over how these various injury criteria are to be applied, and I think there probably will be for a number of years. (In the case of the NASA seat data that were presented, the seat pan acceleration and pelvis acceleration follow each other very closely, hence it is probable the "pelvis DRI" and "seat pan DRI" would be comparable.)

Q: Dick Coykendall, United Airlines

Had the impact been executed to plan, what were the anticipated accelerations that would have been encountered in the distribution of seats?

A: Ed Fasanella, Kentron

That's a good question. If the impact had occurred nearly flat, without roll (or yaw), I would have expected all the acceleration levels to be considerably higher. Also if the nose had been pitched up (as planned), the levels would have been higher in the rear of the airplane, which would be different than what we observed. But what the actual levels would have been in the seats is uncertain unless we repeated the test to find out.

Comment: Bob Hayduk, NASA Langley

Well, we do have some information in the section tests that we did. We had taken Boeing 707 sections and dropped them vertically at about 20 ft/s, and there we experienced acceleration levels along the floor in the neighborhood of 12 g's in the soft sections (fore and aft sections). In the hard center section that we dropped we saw acceleration levels that were in excess of 70 g's on the floor. So I think a nose-up level (no roll) impact where we would have impacted on the rear part of the aircraft would have generated much higher vertical levels throughout the aircraft.

A: Ed Fasanella, Kentron

Yes, it's true we've done quite a few section drop tests and they were very useful for studying a more controlled-type experiment where we have only a vertical velocity component. Levels in the section tests, as Bob Hayduk has said, were higher than those in the CID test, where the wing impacted first.

Q: Dan Watters, Naval Air Test Center

Is it safe to conclude from your standard NASA seat and energy absorbing seat that there's not a significant difference between the two?

A: Ed Fasanella, Kentron

No, that's not really the case. What we had here was a mild impact, especially in the rear part of the fuselage. Since the impact was mild we had no stroking of the energy absorbing seat. In that sense, since the impact was mild and there was no stroking, both seats responded about the same. But in a more severe impact, the stroking EA seat should have shown an improvement over the standard seat.

Comment: Steve Soltis, FAA

I think the point about the type of g levels you might see at higher velocities based on the section tests is that the 10 to 12 g range is usually a pretty long duration such as you saw on the CID, approximately 0.1 to 0.5 seconds. The 70 g's on the hard sections would probably be for about 10 to 30 milliseconds and the occupant might not respond to that. So the pure g level isn't really the whole criterion for a test.

A: Ed Fasanella, Kentron

That is correct; when you talk about g's, the duration is very important. You must always keep the duration in mind.

Comment: Steve Soltis, FAA

I'd just like to make one other comment with respect to this 12 g - 70 g range. I think the 12 g is probably the number I would feel you'd see on the aircraft based on some of the section drop tests and the drop test of a full-scale aircraft (Boeing 707) we saw at Laurinburg, N. C. If you just drop a section you're going to get very high levels in the hard sections because there's no crush distance when it behaves as a section. If you impact a complete aircraft you do get crushing in the hard section which will reduce the load level well below 70 g's.

PRESENTATION BY E. ALFARO-BOU: "STRUCTURAL LOADS - PRELIMINARY RESULTS"

Q: Speaker unknown

In the video tape, I thought I saw a seat attachment failure in the left side of the airplane; it looked like one was becoming detached.

A: E. Alfaro-Bou, NASA Langley

When I was talking about the seats, I was talking about the seat experiment that NASA had. NASA only had two seats and they were towards the rear in body station 1220 and we did not see any failures.

A: E. Fasanella, Kentron

I'd like to clarify the comment about seat attachments. On the NASA seats we couldn't even find the seat after the crash, so we don't even know if it was completely consumed in the fire.

PRESENTATION BY E. L. FASANELLA:

"DIGITAL FILTERING AND ACCELERATION PULSE INTERPRETATION"

Q: John Clark, NTSB

I have the delta V at 14 ft/s, but where are we looking at that velocity change?

A: Ed Fasanella, Kentron

The velocity varies according to where you're located on the plane. After the wing hit, the plane pitched over and came in nose first. You get a variation in velocity from front to rear with the velocity higher in the front. For body station 540, where I showed the trace, the actual total velocity (vertical) integrated out to be 17 to 18 ft/s. It looked like the wing lowered the vertical velocity by about 3 or 4 ft/s since the fuselage impact delta V was about 14 in the example I showed you. That's typical of a good result.

A: Bob Hayduk, NASA Langley

I think that result is also verified by the theodolite data that Dryden has.

Q: John Clark, NTSB

In one other area I noticed there were differences from 14 to 17 ft/s. Was this due to noise in the data or are there other reasons for that?

A: Ed Fasanella, Kentron

The velocity change is sensitive to various things. One problem is that if I have a zero g offset and then integrate, the velocity will be thrown off. We had to go back and correct for zero g shifts even though we were careful to do prefires. Also, the nature of the digital system which jumps essentially in 1-g increments causes errors to occur when accelerations are integrated to produce velocity changes. It's a combination of these things, so you can't quote values to the nearest decimal point.

Q: Gil Wittlin, Lockheed

I have a couple of questions. Is what you call 100 Hz defined as being something like a 3 dB dropoff at 100 Hz?

A: Ed Fasanella, Kentron

That's correct.

Q: Gil Wittlin, Lockheed

Are your cutoff and terminating frequencies (10 and 180 Hz) selected by you, or are they automatic for that type of test?

A: Ed Fasanella, Kentron

I can put anything I want in the program. I just chose those values more or less to make them fall into SAE Class 60 characteristics.

Q: Gil Wittlin, Lockheed

If your sampling rate was higher could you presumably get some higher peak data?

A: Ed Fasanella, Kentron

Yes; we had to change our filter slightly. We had to input the sample rate into the digital filter program. It does change things slightly, but not a whole lot.

Q: John Clark, NTSB

If we had this 4 ft/s velocity change when the wing impacted, how much was proportional to the #1 engine and how much to the #2 engine?

A: Ed Fasanella, Kentron

There may be a chart that tells the exact times that the #1 and #2 engines hit. You can take those times, I guess, and get an idea of the respective contributions, but I don't have those figures in my head right now.

Q: Dick Chandler, CAMI

Do I understand from your earlier comment that the resolution from your acceleration measurements was 1 g?

A: Ed Fasanella, Kentron

It depends. For an 8-bit system you have 0 to 255 (counts or divisions), essentially, and we were ranging our accelerations vertically from +150 g's to -150 g's, so we are around 1 g (resolution) vertically. The resolution goes to 1/3 g in the transverse direction. I think for longitudinal we were ranging to ± 100 g's. It's less than a g per division there. It's a trade-off we had to make; i.e., number of channels, range, resolution, bit rate, etc.

Q: Dick Chandler, CAMI

I was wondering if, with the relatively low resolution in your vertical measurements and your relatively low full-scale values, you are really talking about a potential for a fairly significant error in your data?

A: Ed Fasanella, Kentron

Well, you have to be careful in interpreting the data. The levels were very low in this case, so you have to be careful because of the resolution problem.

Q: Robert Winter, Grumman

I'm not sure I quite understand something and I'd like to get it straight. It looks like you had hardwire analog filtering on the instruments and then processed it digitally later. Is that correct?

A: Ed Fasanella, Kentron

Yes, that's correct.

Q: Robert Winter, Grumman

Were there 60-, 100-, and 180-Hz analog filters on board and did you filter the data later on at 100 Hz?

A: Ed Fasanella, Kentron

We had some analog 60-Hz filters on board the plane, but only a very few. We bought a large number of 180-Hz analog filters initially, so when we later reduced the total number of channels we had a surplus of filters and did not buy many 60-Hz filters. It doesn't make a whole lot of sense to use an analog filter of 60 Hz and then digitally filter at 100 Hz (except for some smoothing), but there were very few acceleration channels with 60 Hz analog filters.

Q: Robert Winter, Grumman

When you present the curves that are labelled "digitally filtered" and "unfiltered," aren't the curves labelled "unfiltered" really data that were recorded with 100-Hz analog filters?

A: Ed Fasanella, Kentron

Yes, they were either 180- or 100-Hz analog filtered. But you see, the digital filter is much sharper than the analog filter. The analog filter really passes a lot of the high frequencies, but the digital filters are very sharp in comparison. You wouldn't have a hardwire type analog filter that's as sharp as the digital filter. You can compare them, but it's like comparing apples and oranges. You have to look at the response curve of the digital filter and the response curve of the analog filter to really compare them.

PRESENTATION BY RICHARD E. ZIMMERMAN: "PRELIMINARY
FLOOR, SEAT, AND DUMMY DATA"

Q: Dick Coykendall, United Airlines

During a vertical acceleration such as on seat A during ground impact, the pelvis response shows a very definite double peak response that lasts something like 100 milliseconds. Is that consistent with what the theoretical dummy response would be? What is the explanation of the obstacle impact producing higher vertical accelerations?

A: Dick Zimmerman, Simula Inc.

What amplitude were you looking at?

Q: Dick Coykendall, United Airlines

The amplitude was about 6 g, but the question concerns the two-peak response with a period of about 100 milliseconds between peaks. Is that consistent with the theoretical dummy behavior?

A: Dick Zimmerman, United Airlines

It is not unusual. In response to your second question, why we got the vertical response in the obstacle impact when the aircraft was obviously just sliding along the ground, I can't really explain. All I could offer would be conjecture. There were things happening to the aircraft, such as those obstacles tearing the structure underneath it. The landing gear was coming up underneath, pushing up on the floor. Perhaps the airframe climbed up on these obstacles a bit. That would be about the only reason you would see a vertical acceleration in that impact.

A: Bob Hayduk, NASA Langley

As further verification, those obstacles were very strong ones, built out of heavy steel. When they impacted the fuselage there was a pretty strong upward load on the fuselage due to the fuselage trying to come up over the top of the wing openers. I believe that the explanation for the substantial vertical load is the fact that they were so rigidly planted in the ground.

A: John Clark, NTSB

Basically, it was the heavy center structure impacting the wing cutters that produced the vertical load. However, in conjunction with that keel beam, is that why one chart shows the peak floor acceleration below seat F at 120? Is that still g's or is that a different scale?

A: Ed Fasanella, Kentron

I think I would disregard that trace entirely. I think it is bad data.

A: Dick Zimmerman, Simula, Inc.

The data for the channel at seat F was consistent with all other channels during ground impact. Somewhere as the aircraft was sliding along the ground something happened to that data channel. I can't tell you what happened to it that made it increase in amplitude like that but I also think it's wrong.

This morning Ed Fasanella was talking about validating this data. I showed you the number of channels we had for the seats and I said we only lost 10 of them. There are other channels that will have to be looked at very hard and validated, as Ed said. One of the checks, as he pointed out, is to integrate the data and see if the velocity checks out. For seat F it does not; the velocity is much too high. I think that data shows something about what was going on there, but it is not the right amplitude.

Q: John Clark, NTSB

When the cutters ripped through the fuselage, the no. 1 cutter sliced through and hit the main gear right under that seat with the high output. There was a lot of damage. It took out the keel beam just ahead and went into the left gear strut and knocked it completely out of the airplane. That was right under the seat where the data is, where we got that 120 g. That may be part of the problem. Part of the vertical acceleration could also have come from the plane trying to rise up on the gravel. There is about a 6 to 8 inch very gradual lift and that is also consistent with the total depth and crush that we had at the initial contact, so that could be a source of vertical loading. The whole airplane had to rise 6 inches when it slid across the gravel. What I would like to know is how the overhead bins fared, whether they stayed in place.

A: Dick Zimmerman, Simula, Inc.

They burned up on the ground.

Q: John Clark, NTSB

How were they loaded? What kind of luggage was put in, and did the latch stay closed during the sequence?

A: Dick Zimmerman, Simula, Inc.

They were loaded with a 60-lb mass bolted to the door.

Q: John Clark, NTSB

Was this the placarded weight of the bin or was it a lighter load? Was this a Boeing wide-body bin?

A: Roger Lloyd, RMS Technologies

It came out of a Boeing 707.

PRESENTATION BY LEO J. GARODZ: "CONTROLLED IMPACT DEMONSTRATION
FLIGHT DATA RECORDERS/COCKPIT VOICE RECORDERS"

Q: Dick Tobiason, RMS Technologies

Am I correct in saying that the foil recorder behaved as you expected it to behave, and three digital recorders malfunctioned for 5 to 7 seconds after touching?

A: Leo Garodz, FAA

I can't answer that on the foil recorder. I don't know what might have happened afterwards if we had added electrical power to the unit. This system was tied into the airplane's electrical power unit. It was not tied into my inverter and battery pack.

Q: Speaker unknown

Could you amplify a little more on the digital flight recorder response - the 5 to 7 seconds of malfunction? You made a statement that the three digital flight recorders had a 5- to 7-second malfunction time after impact, and they were on standby independent power with your inverter and battery pack.

A: Leo Garodz, FAA

Some of them started to operate again properly; however, we lost certain transducers during the impact with the wing openers. For example, we lost our triaxial accelerometer. It was in a keel section which was ripped out immediately. But we continued to get the pitch and roll signals on the three flight data recorders.

Q: Speaker unknown

The slideout was about 10 or 11 seconds. Are you saying that you have 3 to 4 seconds worth of data after touchdown after that malfunction period?

A: Leo Garodz, FAA

Yes.

PRESENTATION BY J. D. PRIDE: "LARC PREFLIGHT HARDWARE TESTS"

Q: Speaker unknown

What was behind your decision for your high-temperature environmental test of 120°F operational and 160°F nonoperational?

A: Joe Pride, NASA Langley

The operational comes out of the TRCA 106A document for turbojet aircraft for thermal. The 160°F nonoperational came from conversations with NASA Dryden about their experience with aircraft sitting out on the hot lakebed during the summer. Because the aircraft was not air conditioned over the weekends, we designed the system to survive these temperatures.