comes out in foot pounds as 1,454,700,000.

THE COURT: I noticed that.

MR. LEWIS: And that seems to me, Your Honor, it is a lot of force.

THE COURT: Well, thank you, Mr. Lewis.

That is where I got short circuited on this thing, Mr. Dubuc. When I realized that the jury was being told 1.45 times 10 to the 9th power, when the jury would understand it better if you said 1,450,000,000 foot pounds.

This thing is getting to be a magic show here.

MR. DUBUC: We are not trying to do that.

THE COURT: Well, somebody didn't try to do it. They did it.

MR. DUBUC: First of all, Your Honor, I don't believe he is saying anything about constant speed. He is talking about a constant deceleration rate. That is what he is talking about.

THE COURT: Constant deceleration?

MR. DUBUC: Deceleration.

THE COURT: He said constant speed.

MR. DUBUC: Maybe we can read it back.

But I think what he is talking about is a constant deceleration. And we have had testimony to that effect already from several witnesses who have described, at least the people that were in the airplane, deceleration.

If he said "speed", that is not what he meant to say. I will ask him to correct that.

I am talking about deceleration.

He has a formula and he has done also the connectic (sic) energy computation. If you want him to amplify that, fine. I was going to save the time of doing it, but I will be glad to have him amplify it.

I am trying and only proffering a similiar kind of expert's testimony that is designed as my rebuttal to Mr. Timm's, who was permitted to testify about a terminal impact, as Your Honor knows, of massive magnitude of force under situations of terminal impact.

THE COURT: I'm not very sympathetic to the suggestion that this is a surprise because I don't see how this case could have been tried without this kind of calculation. And I assumed there would be one on both sides. It is elementary.

But I am concerned about the confusion that is injected by using this 9th power, which has the affect of distracting the jury from the point.

I am also concerned about the mixing of bricks and straw, namely, calculations and a lot of argumentation and the repetition of the argument for emphasis. That witness ought to give us the information and get off the stand.

MR. DUBUC: All right.

THE COURT: So, let's do that.

MR. DUBUC: If he doesn't want him to complete the calculation, I can just leave it.

THE COURT: Let's complete the calculation.

MR. DUBUC: Complete the calculation. Okay.

Then I would like to ask him kinetic energy and make it clear rather than putting it the way Your Honor or the way it was suggested by counsel. I will ask him about kinetic energy and I will ask him what affect deceleration has on existing kinetic energy of a body.

THE COURT: Let me see what Mr. Lewis' other objection is.

MR. LEWIS: Your Honor, the first thing I would call to the Court's attention is that Dr. Stark, who was in the troop compartment and their witness, said that the deceleration of the troop compartment was a series of crashes. I can find it, given the opportunity, but that is clearly what he said. He didn't suggest that it was smooth at all.

THE COURT: You get the impression that this thing is just gliding through vasoline.

MR. LEWIS: No, I don't think so, Judge.

THE COURT: That is the way the testimony is.

MR. LEWIS: That is right, sir.

Their witness said it was a series of crashes. I can find it and I will ask counsel to do that.

THE COURT: You don't have to remind me of that. I remember that.

The point is this is still the basic really arithmetic of this situation and it seems to me it is essential to the case. You can do all kinds of things on cross-examination. But I don't think it is objectionable to introduce Newton's law into this accident.

MR. LEWIS: I don't either, Judge.

The problem is that Newton's law requires the element of time. They have no deceleration time, Judge. If you knew how quickly that troop compartment or whatever decelerated from one speed to another that is how you get the "G" forces, Your Honor, and it just cannot be done without knowing that element and he doesn't know that element and none of these people are able to give any estimate of it with any kind of reliability. And that is very essential.

THE COURT: Won't that come out on cross-examination?

MR. LEWIS: Well, Your Honor --

THE COURT: See, we have a situation here. Even though we don't know the quantity of it, we know that there was an impact, a very large impact, and a dispersion of the force.

Now, the jury, I don't know whether any of the jurors know physics or not. They are entitled to have some explanation. They are going to be like in Plato's cave. They are going to see it very dimly because it isn't done with a very bright light, probably because there isn't much data.

To me this is as fair a way as illustrating it as describing an impact of two railroad trains going head-on fifty miles an hour. Because there wasn't a head-on collison, any more than there was a deceleration over a period of time.

If we believe in the jury system, and if you cross-examine effectively, they will have an adequately bright, relatively dim view of what happened.

MR. LEWIS: Well, if it please the Court, the witness on voir dire said to me the element of time. And I would ask as a proffer of what time they say this matter decelerated.

THE COURT: He has a formula here that asks him to give not time, but time squared, and he has to fill that in. I don't know how he is going to do it. Maybe he has an assumption for that.

MR. LEWIS: This is presumably upon the basis of a hypothetical, Your Honor. He asked him to assume this, that and the other thing.

THE COURT: Let's hear the proffer.

What is the time in this formula?

MR. DUBUC: The time?

I will have to ask Mr. Edwards about the time.

THE COURT: Bring Mr. Edwards back.

[Whereupon, Mr. Edwards enters the courtroom and resumes the witness stand.]

THE COURT: Mr. Patrick, pull that back so that Mr. Dubuc can see his witness.

Do you want to make that inquiry very quickly?

BY MR. DUBUC:

Q Well, Mr. Edwards, the question has been raised as to your formula, which is the distance of the velocity versus time in a voir dire response.

Can you tell us how you took care of the factor of time?

A Yes, I can.

I started to show you the mathematics as to how you can take distance and velocity and get time from that and/or acceleration.

Q How do you do that?

Do you need the board to do it?

A I would like to go through it on the board for you, if you don't mind.

THE COURT: I have the formula very mucy in mind and in my head.

Do you assume time or do you calculate time by having distance and velocity?

THE WITNESS: I calculate time by having distance and velocity.

THE COURT: And velocity is assumed to be 270?

THE WITNESS: That is correct.

MR. LEWIS: May I ask one question?

THE COURT: Yes.

Let Mr. Lewis inquire a little further.

BY MR. LEWIS:

Q It would make a difference, wouldn't it, if it was not a smooth, constant rate or deceleration?

A Yes, it would.

Q Have you taken anything into consideration on the question of whether it was a smooth or constant rate of deceleration?

What data do you have, if any, on that?

What elements have you considered?

A I took some things into consideration, yes, I did.

Q Did you take into consideration Dr. Stark's testimony?

A Dr. Stark?

Q Yes.

The passenger in the troop compartment.

A I don't know if I recall anything from Dr. Stark.

Q Let me ask you this.

Did you take into consideration the fact of the sentence that I'm going to read you out of the accident investigation report: Approximately halfway through the turn the aircraft nosed down at a rapid rate. Seeing that they would be unable to reach the runway, the pilot rolled the wings level and applied power to the full throttle capacity. All landing gear was noted in the down and lock position by the flight engineer. Immediately prior to the impact the pilot retarded the throttle to idle.

Did you take that into consideration?

A Yes, I did.

Q Now, during the period that the full throttles were going on, there was no recording of the power and velocity; was there?

A I don't believe you can say that is correct, sir.

Q I thought you said three point some seconds before the first touchdown there was no recording of velocity on the MADAR tape?

A That is correct.

THE COURT: I understand that.

Let's get the jury back and complete this.

4a

I will take a five-minute recess.

[Recess.]

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(Whereupon, the following took place outside of the hearing of the jury:)

Whereupon,

CAPTAIN JOHN EDWARDS

resumed the stand and testified further as follows:

THE COURT: Are you going to continue with the calculation?

MR. DUBUC: I thought that is what you wanted me to do.

THE COURT: I think you better terminate so that Mr. Lewis will be able to develop the difference between the figures.

MR. DUBUC: He has got the G figures there.

Can I ask him a question about the kinetic energy versus the G force?

THE COURT: I think the way this thing fell, I think Mr. Lewis is entitled to develop the point. I can't think of any other fairer way to do it.

MR. DUBUC: I was going to tie his testimony on kinetic energy which he has computed to what he has done on the G force, then my examination will be complete.

THE COURT: If you correct the 1.4547 that I have, the 1.4547 X 10 to the 9th power without Mr. Lewis having an opportunity to correct it on cross-examination, I will have to say something to the jury about it.

jc2

MR. DUBUC: No, I am going to ask him about the statement about kinetic energy made by another witness. He has calculated it into Gs. I am going to ask him what kinetic energy is and what happens on deceleration such as he described.

THE COURT: Then Mr. Lewis can cross-examine?

MR. DUBUC: Yes.

THE COURT: Bring back the jury.

(Whereupon, the following took place in open court:)

THE COURT: Mr. Dubuc.

DIRECT EXAMINATION (Continued)

BY MR. DUBUC:

Q You have told us about the computation with some G forces. Previously you mentioned a computation you made as to kinetic energy. Do you recall that?

A Yes, I do.

Q Is kinetic energy by itself a force?

A Kinetic energy as a mathematical formula is a certai mass traveling at a certain velocity.

As to "energy" against the word "force," Mr. Dubuc, force is when you push against the table. Energy is something that is traveling and moving.

Q If you have a certain force, kinetic energy moving at a certain force, and you disrupt or stop that movement immediately or suddenly such as hitting an object, such as

jc3

hitting a mountain or something of that nature, would that be called a terminal impact of the kinetic energy?

A It would be a good way to phrase it.

Q If you stopped that moving kinetic energy in a different manner so it is not a terminal impact, but so it is an impact or several impacts over time with a deceleration as you have described in those pictures in your computations, is that a different quantum of kinetic energy?

A It would be different in that the deceleration would be quite different if you stop over a distance, differen from like you are immediately locked against a mountain.

Q As to the period or time in which the kinetic energy is dissipated in this series of pictures you have shown us, does that differ insofar as the force operative on an object such as an airplane or car or whatever it might be?

A I don't think there really would be any difference. In stopping an automobile, you go through the same deceleration and the same G forces on a human body, may be a different magnitude than you would on an airplane.

Q You told us, I think, that the Troop Compartment and the Flight Compartment of this airplane were approximately two stories above the street and you said that has some importance.

What importance, if anything, does that have with

jc4

respect to what you have been telling us about deceleration forces?

A The importance of that two stories of structure between the aft Troop Compartment and the crew deck and the bottom of the tires on the airplane is that as the airplane made the second impact and as this kinetic energy was being dissipated by the airplane dragging through the rice paddies, the dragging through the rice paddy eroded away the structure and it tore off in chunks and this dissipated, burned up the kinetic energy and it dissipated it over a period of time and that is why this aft Troop Compartment traveled this 2,000 or so feet.

During that period of 2,000 feet that there was friction between the airplane and the ground, it was slowing the airplane down and it was breaking off chunks of the aluminum structure.

Q You mentioned something about the structure folding back during this period of time, the wing structure around the Troop Compartment?

A Yes, the wreckage area shows some 850 feet from the second impact that the aircraft structure had eroded away to the point where a big section of the cargo floor was left lying there in the rice paddy about 850 feet from the dike.

When the floor eroded away and the side panels having no support, then they were dragging through the rice paddy and eventually they just kind of folded up like wings and still gave you a good friction force and stopping point.

Q Based on the diagram and the computation and, as you have told us, of the wearing away and dissipation of energy; based upon your calculations, would the G forces be different in different parts of the airplane?

A The G force is a function of the velocity, the initial velocity, and then the distance it traveled. Certain sections of the airplane did travel different distances, therefore the average acceleration or deceleration would be different because it traveled a different distance.

Q Would that be one of the reasons why your figures in the G forces in the Troop Compartment were far less than the figures in the Cargo Compartment?

A Yes, that is the sole reason. It is strictly a function of distance because the initial velocity was the same in all cases.

MR. DUBUC: Thank you.

CROSS-EXAMINATION

BY MR. LEWIS:

Q Sir, the formula you gave us for kinetic energy which is the amount of kinetic energy existing at the time, both times the airplane hit the ground, the first and the second time; was that the same? Is that correct?

A I don't recall that I gave you the complete formula,

jc5

but the formula for kinetic speed is the same.

Q It was 1.4547 X 10 to the 9th power which gives you a result in foot pounds?

A If the speed is the same in both places and recorded data indicates it was, or very close, and if the mass of the airplane was the same, then it would be the same.

Q That comes out in foot pounds to 1,454,700,000 foot pounds; doesn't it?

A I believe that is another way of saying 1.4547 X 10 to the 9th power.

Q You agree with me, I am correct?

A That is correct, yes.

Q Now, when you did your calculations, sir, did you take into consideration that the section that the babies were in halted in a series of crashes as opposed to a smooth velocit

Did you take that into consideration?

A My observation of the wreckage area --

Q Say yes or no.

A No.

Q Let me read to you the testimony of a Dr. Stark who was in the Troop Compartment, and this is how he described the deceleration of the Troop Compartment, sir.

It is on page 2,101 of the transcript of this proceeding, starting in the vicinity of line 5 and on.

He said, after asking him to describe the impact,

jc6

"There was an initial impact which was certainly hard, but the plane didn't explode or anything like that which is sort of what I had anticipated might happen. Then following this initial touchdown, then there was a series of crashes as the plane crashed across the landing area."

Now, if that is a true statement, sir, that would not be a constant velocity, would it?

A I don't know what sensations the doctor was experiencing, so I couldn't really comment on that.

Q Consider what he says here. He says, "Then following this initial touchdown, then there was a series of crashes a series of crashes as the plane crashed across the landing area. This took a matter of, I guess, a few seconds -- it seemed much longer -- but finally the plane came to a complete halt."

Just analyzing that statement, doesn't that seem to say that the airplane, at least the part that he was in, banked and then moved farther and banked again and moved farther and banked again? Isn't that what that seems to say?

MR. DUBUC: Objection. He should read that in the entire context.

THE COURT: You will have an opportunity on redirect examination.

BY MR. LEWIS:

Q Isn't that what it seems to say?

A Counsel, taking that statement and analyzing that statement in conjunction with what I actually saw on the scene --

Q I am asking you, did you take into consideration --

THE COURT: You have asked that.

MR. LEWIS: I am sorry.

BY MR. LEWIS:

Q If this were true, if what Dr. Stark said were true, then there would not be a constant velocity, would there?

A I would have to say I would have to analyze this statement in conjunction with other evidence, physical evidenc onsite before I could conclude what he really experienced.

Q If you were just taking what he says now, if that is true, then there was no constant velocity, was there?

MR. DUBUC: Objection.

THE COURT: That is sustained.

MR. LEWIS: I understand. My point is I don't feel I got an answer.

THE COURT: I don't want any comment.

MR. LEWIS: All right.

BY MR. LEWIS:

Q Who is Mr. Gregory?

Do you know a Mr. Gregory?

A Yes.

Q Russell L. Gregory?

File Proj 1289

New York City
212-892-0153

WILLIAM TIMM and Associates

Westchester
914-273-3098

12 LAUREL HILL PLACE, ARMONK, N.Y. 10504

received
6/28/80

June 26, 1980

Cromack Engineering Assoc., Inc.
P. O. Box 28243
Tempe, Ar 85282

ATT: Mr. J. Robert Cromack, P.E.
SUBJ: Inspection of C-5A Aircraft **at** Kelly Air Force Base.

Dear Mr. Cromack:

It was a great pleasure to work with in June 19, 1980 in San Antonio, Texas where we inspected a C-5A Aircraft and the parts recovered from the Siagon crash April 4, 1975. Recent developments make the determination of the forces required to dislodge or break the seats in the troop compartment of vital importance to this case. The judge may change his opinions and release the moneys from case one and three if it can be shown that substantial force is required to break these seats loose from the aircraft.

During the inspection of the existing aircraft you were taking the most detailed notes of the seat construction, and probably are in the best position to calculate these forces. My notes indicate that a 3/8" bolt fastened the frame of the seat to a plate which connected to the floor flanges. The flanges were held in position by four screws which were assumed to be at least a number ten screw at maximum.

This aircraft was built with a 7075-T6 and 7079-T6 aluminum alloys and have the following properties:

	Aluminum Alloys 7075-T6	7079-T6
Modulus of Elasticity in kips per square inch, tension and compression	10,400	10,400
Modulus of Elasticity in kips per square inch, Shear	3,900	3,900

The ultimate strengths and yield strengths depend on whether the alloy is sheet or plate, extruded rods, bar or shapes, cold rolled rods or bars, pipe, extruded tubing; the strengths also depend on the thickness of the material or section. This data can be obtained out of the Alcoa Structural Handbook and I have copied the appropriate pages and enclosed them for your information.

-continued-

The 7075-T6 and the 7079-T6 heat treated aluminum alloys are highly sensitive to stress corrosion which is known to degrade the strength of the high stress alloys. The C-5A aircraft has a serious defect in the wing structure which has reduced the service life of this wing from a design of 30,000 hours to less than 9,000 hours because of the fatigue cracking in the wings. The wings have been overhauled to give only an additional 10,000 hours of life after a considerable expenditure of funds on this modification.

The summary of the accident report, which you already have in your possession, is about the best document which gives the events leading up to this crash. The collateral report is almost identical to the accident report and does not add anything to the events up to and including the crash.

If I knew what additional data you require, I probably could locate the document in which this data appears, if it is available. The best description I can give you for the loading of the seat is as follows: The orphans were loaded two to a seat with the heads of the orphans placed closest to the back of the seat, and were held in the seat by a pillow placed over both babies and fastened in with the seat belt. The children ranged in age from 6 to 20 months of age and were quite small; a weight of 15 to 20 lbs. per baby would be quite high for determining the loading in each seat.

I have enclosed a copy of the time-altitude data which has been collected from various sources: The first set of data is the first altitude-time data given us by the Government which was ploted as altitude verus time and G-forces in the vertical direction were calculated. The summary of these sheets are enclosed for your information.

Madar data was furnished from the Air Force which gives the time, altitude and mach number; all data with a star does not have a corresponding data point from the Madar tape computer runout which was furnished from Lockead. The last column gives the time intervals in which the altitude and mach number correspond to the Lockheed Madar tape data.

A Madar system is the abreviation for the malfunction automatic data acquisition and recording system which is refered to as MDR in the accident report or malfunction data record.

I am also furnishing you with a copy of the wreckage diagram along with a copy of the April 18, 1980 letter Warren R. Lewis Jr. from Carol E. Dubuce for your information and study. I have been unable to determine the accuracy of the Lockheed calculated data, nor do I have a key for the recording of the SLRP (05) message on record 11977. This letter does not explain any of this data but you may be able to derive something from it.

I am also enclosing a copy of Mr. Edwards April 28, 1980 calculations for the average G-force on this aircraft. This information should get you started in being able to analyze and understand the testimony which has been given so far.

Very truly yous,

William Timm

William Timm, P.E.
Consulting Engineer

WT:vh
Enclosures

TABLE 4a

Minimum Mechanical Properties and Buckling Formula Constants—Concluded

SHEET AND PLATE

See page 39 for explanation of "minimum" properties.
US = ultimate strength in kips per sq in., YS = yield strength in kips per sq in., El = elongation in per cent in 2 in. or 4 dia.
See pages 39 to 41 for definitions, methods of determination and notes.

Alloy and Temper	Thickness, In.	Minimum Mechanical Properties								Buckling Formula Constants					
		Tension			Compression	Shear		Bearing		Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B	D	C
5456-O	0.051-2.000	42	19	16	19	26	11	84	38	21.6	0.120	111	13.0	0.056	145
5456-H24	0.051-0.249	51	39	9	38	30	22	97	62	45.1	0.368	79	27.2	0.170	100
5456-H321	0.126-0.249	46	33	12	31	27	19	84	53	36.5	0.265	88	21.9	0.123	112
5456-H321	0.250-1.250	46	33	12	32	27	19	84	56	37.7	0.278	86	22.6	0.129	111
5456-H321	1.251-2.000	44	31	12	30	26	18	80	53	35.2	0.251	89	21.1	0.116	115
5456-H323 or H32	0.126-0.249	48	36	8	34	28	21	91	58	40.3	0.308	85	24.2	0.143	107
5456-H343 or H34	0.051-0.249	53	41	*	39	31	24	101	66	46.7	0.354	78	28.0	0.178	100
6061-O	0.010-3.000	16	6	*	6	11	3.5	33	15	6.5	0.019	185	3.9	0.009	246
6061-T4	0.010-3.000	30	16	*	16	20	9	63	26	18.0	0.092	128	10.8	0.042	152
6061-T6	0.010-3.000	42	35	*	35	27	20	88	58	39.9	0.263	65	23.9	0.122	88
Alclad 6061-O	0.010-0.500	16	6	*	6	11	3.5	33	15	6.5	0.019	185	3.9	0.009	246
Alclad 6061-T4	0.010-3.000	27	14	*	14	18	8	57	22	15.7	0.074	128	9.4	0.034	162
Alclad 6061-T6	0.010-3.000	38	32	*	32	24	14	80	51	36.3	0.228	71	21.8	0.106	92
7075-O	0.015-2.000	29	12	*	13	19	7	61	29	14.5	0.066	155	8.7	0.030	165
7075-T6	0.008-0.011	74	63	5	65	45	36	140	103	77.4	0.711	49	46.4	0.330	63
7075-T6	0.012-0.039	76	65	7	67	46	37	144	106	80.0	0.747	48	48.0	0.347	62
7075-T6	0.040-0.249	77	66	8	68	46	38	146	107	81.3	0.765	48	48.8	0.356	62
7075-T6	0.250-0.499	77	66	8	69	46	38	139	100	82.6	0.784	47	49.6	0.365	61
7075-T6	0.500-1.000	77	66	6	69	47	38	142	104	82.6	0.784	47	49.6	0.365	61
7075-T6	1.001-2.000	77	66	4	68	46	38	140	102	81.3	0.765	48	48.8	0.356	62
7075-T6	2.001-2.500	73	62	3	65	44	36	131	93	77.4	0.711	49	46.4	0.330	63
7075-T6	2.501-3.000	70	60	3	63	42	35	126	90	74.9	0.677	50	44.9	0.314	64
7075-T6	3.001-3.500	68	58	3	62	41	33	122	87	73.6	0.659	50	44.2	0.307	65
7075-T6	3.501-4.000	66	56	2	60	40	32	119	84	71.0	0.624	51	42.6	0.290	66

Alloy and Temper	Thickness, In.	Minimum Mechanical Properties								Buckling Formula Constants					
		Tension			Compression	Shear		Bearing		Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B	D	C
Alclad 7075-O	0.008-0.062	27	11	*	12	18	6.5	57	26	15.3	0.058	172	8.0	0.027	181
Alclad 7075-O	0.063-1.000	28	12	10	13	18	7	59	29	14.5	0.066	155	8.7	0.030	165
Alclad 7075-T6	0.008-0.011	68	58	5	60	41	34	129	95	71.0	0.624	51	42.6	0.290	66
Alclad 7075-T6	0.012-0.039	70	60	7	62	42	35	133	98	73.6	0.659	50	44.2	0.307	65
Alclad 7075-T6	0.040-0.062	72	62	8	64	43	36	137	101	76.1	0.693	49	45.7	0.322	64
Alclad 7075-T6	0.063-0.187	73	63	8	65	44	36	139	102	77.4	0.711	49	46.4	0.330	63
Alclad 7075-T6	0.188-0.249	75	64	8	66	45	37	142	104	78.7	0.729	49	47.2	0.338	63
Alclad 7075-T6	0.250-0.499	75	64	8	66	45	37	135	98	78.7	0.729	49	47.2	0.338	63
Alclad 7075-T6	0.500-1.000	75	64	6	66	46	37	139	99	78.7	0.729	49	47.2	0.338	63
Alclad 7075-T6	1.001-2.000	75	64	4	66	45	37	137	99	78.7	0.729	49	47.2	0.338	63
Alclad 7075-T6	2.001-2.500	71	60	3	62	42	35	128	90	73.6	0.659	50	44.2	0.307	65
Alclad 7075-T6	2.501-3.000	68	58	3	61	40	33	122	87	72.3	0.642	51	43.4	0.298	65
Alclad 7075-T6	3.001-3.500	66	56	3	60	39	32	119	84	71.0	0.624	51	42.6	0.290	66
Alclad 7075-T6	3.501-4.000	64	54	2	58	38	31	115	81	68.5	0.592	52	41.1	0.275	67
7178-T6	0.015-0.044	83	72	7	73	50	41	158	117	87.8	0.859	46	52.7	0.399	59
7178-T6	0.045-0.249	84	73	8	74	50	42	160	118	89.1	0.878	46	53.5	0.408	59
7178-T6	0.250-0.499	84	73	8	74	50	42	151	111	89.1	0.878	46	53.5	0.408	59
7178-T6	0.500-1.500	84	73	*	74	50	42	151	112	89.1	0.878	46	53.5	0.408	59
7178-T6	1.501-2.000	80	70	3	71	48	40	144	106	85.2	0.821	47	51.1	0.381	60
Alclad 7178-T6	0.015-0.044	76	66	7	67	46	38	144	107	80.0	0.747	48	48.0	0.347	62
Alclad 7178-T6	0.045-0.249	78	68	8	69	47	39	148	110	82.6	0.784	47	49.6	0.365	61
Alclad 7178-T6	0.250-0.499	78	68	8	69	47	39	140	104	82.6	0.784	47	49.6	0.365	61
Alclad 7178-T6	0.500-1.500	78	68	*	69	47	39	140	105	82.6	0.784	47	49.6	0.365	61
Alclad 7178-T6	1.501-2.000	75	65	3	66	45	37	135	99	78.7	0.729	49	47.2	0.338	63

TABLE 3b

Typical Physical Properties—*Concluded*

CASTING ALLOYS

Alloy	Weight, Lb per Cu In.	Modulus of Elasticity, Kips per Sq In.		Coefficient of Thermal Expansion per Degree F[1], 68° to 212°F	Electrical Conductivity, Per Cent of International Annealed Copper Standard	Thermal Conductivity at 25°C, CGS Units
		Tension and Compression	Shear			
333-F[3]	0.100	......	.....	0.0000115	26	0.25
333-T5[3]	0.100	......	.....	0.0000114	29	0.29
333-T6[3]	0.100	......	.....	0.0000115	29	0.28
333-T7[3]	0.100	......	.....	0.0000115	35	0.34
355-T51	0.098	10,200	3,800	0.0000124	43	0.40
355-T6	0.098	10,200	3,800	0.0000124	36	0.34
355-T6[3]	0.098	10,200	3,800	0.0000124	39	0.36
355-T61	0.098	10,200	3,800	0.0000124	37	0.34
355-T7	0.098	10,200	3,800	0.0000124	42	0.39
C355-T61	0.098	10,200	3,800	0.0000124	37	0.34
356-T51	0.097	10,500	3,950	0.0000119	43	0.40
356-T6	0.097	10,500	3,950	0.0000119	39	0.36
356-T6[3]	0.097	10,500	3,950	0.0000119	41	0.38
356-T7	0.097	10,500	3,950	0.0000119	40	0.37
A356-T61	0.097	10,500	3,950	0.0000119	41	0.38
360-F[3]	0.095	10,300	3,850	0.0000116	28	0.27
380-F[3]	0.098	10,300	3,850	0.0000116	23	0.23
384-F	0.098	10,300	3,850	0.0000113	23	0.23
A612-F	0.102	9,700	3,650	0.0000134	35	0.33
C612-F[3]	0.103	......	.....	0.0000131	40	0.38
750-F[3]	0.104	10,300	3,850	0.0000130	46	0.43
A750-T5	0.103	10,300	3,850	0.0000126	43	0.40
B750-T5	0.104	10,300	3,850	0.0000129	45	0.42

[1] Values of coefficient of thermal expansion for "F" and "T" tempers may vary slightly from one casting to another.

[2] While castings are not commonly annealed, similar effects on conductivities may result from the slower rate of cooling of thick sections as compared with thin ones and other variables in foundry practices. Comparison of the values for as-cast and annealed specimens will show the extent to which variations may be expected, depending upon differences in thermal conditions in the production of different types of castings.

[3] Chill cast samples; all other samples cast in green sand molds.

EXPLANATION OF TABLE 4

Units

All strength values in Table 4 are expressed in kips per square inch. One kip is equal to one thousand pounds.

Dimensions

In many cases in Table 4 it is necessary to show thickness ranges or other dimensional classifications, since the minimum properties of the products vary with these factors. The dimensional ranges shown do not necessarily mean that items outside these ranges are not available. The nearest Alcoa sales office should be consulted for information on limiting sizes of products.

Minimum Values

Most of the tensile properties listed in Table 4 are guaranteed minimum values. The rest of the tensile properties, and also the other quantities in the table, are corresponding minimum expected values but are not guaranteed. Tables of minimum mechanical properties guaranteed by Alcoa are available in another publication, the *Alcoa Aluminum Handbook*.

In all cases the values in Table 4 are for metal at room temperature but may be considered applicable to temperatures from 0° to 150° F. For effects of temperature on properties, see Tables 8a, 8b and 8c, pages 76 to 82.

Wrought Products

Guaranteed minimum tensile properties of wrought products are based on test specimens taken from a specified location and direction in the part and do not necessarily represent the absolute minimum values that could be found anywhere in the part. However, for most design purposes, the guaranteed minimum tensile properties and the other corresponding minimum properties in Table 4 are satisfactory for use as over-all minimum values.

For all wrought products, the minimum tensile properties in Table 4 apply to the direction in which specified mechanical properties are determined. This is the principal direction of working (longitudinal direction) for all products except heat-treated sheet and plate. For heat-treated sheet and plate, specifications require that tensile properties be measured in the transverse direction, since these values are generally lower than the longitudinal properties.

Compressive yield strength values in Table 4 apply to the principal direction of working for all wrought products since compressive yield strength is generally lowest in this direction.

Die Forgings

It is customary to conduct quality control tensile tests for die forgings on separately forged coupons. Except for elongations, the properties so determined are applicable not only to the separately forged coupons but also to specimens that might be cut from the forgings themselves in a direction

TABLE 4b

Minimum Mechanical Properties and Buckling Formula Constants

EXTRUDED ROD, BAR AND SHAPES

See page 39 for explanation of "minimum" properties.
US = ultimate strength in kips per sq in., YS = yield strength in kips per sq in., El = elongation in per cent in 2 in. or 4 dia.
See pages 39 to 41 for definitions, methods of determination and notes.

Alloy and Temper	Thickness, In.	Minimum Mechanical Properties: Tension			Compression	Shear		Bearing		Buckling Formula Constants: Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B_t	D_t	C_t
2014–O	All	24	9	12	9	15	5	50	21	9.9	0.037	160	5.9	0.017	207
2014–T4	All	50	35	12	30	31	20	90	55	35.2	0.251	89	21.1	0.116	113
2014–T6	Up thru 0.499	60	53	7	55	35	31	114	85	61.4	0.410	50	36.3	0.190	[illegible]
2014–T6	0.500–0.749	64	58	7	60	37	33	122	93	67.3	0.471	48	40.4	0.219	[illegible]
2014–T6	0.750 and over Area 25 sq in. max.	68	60	7	62	39	35	109	84	69.7	0.496	47	41.8	0.230	[illegible]
	Area 25 to 32 sq in.	68	58	6	60	39	33	109	81	67.3	0.471	48	40.4	0.219	[illegible]
2024–O	All	25	9	12	9	15	5	52	21	9.9	0.037	160	5.9	0.017	207
2024–T4	Up thru 0.249	57	42	12	38	30	24	108	67	43.6	0.300	65	26.2	0.140	[illegible]
2024–T4	0.250–0.749	60	44	12	39	32	25	108	69	44.8	0.313	64	26.9	0.146	[illegible]
2024–T4	0.750–1.499	65	46	10	44	34	27	108	71	50.9	0.379	60	30.5	0.176	78
2024–T4	1.500–2.999 Area 25 sq in. max.	70	52	10	50	38	30	108	73	58.4	0.466	56	35.0	0.216	[illegible]
2024–T4	3.000 and over Area 25 sq in. max.	70	52	10	50	37	30	108	73	58.4	0.466	56	35.0	0.216	[illegible]
2024–T4	1.500 and over Area 25 thru 32 sq in.	68	48	8	46	36	28	108	72	53.4	0.407	59	32.0	0.189	[illegible]
3003–O	All	14	5	25	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
3003–H112	All	14	5	.	5	10	3	30	12	5.1	0.015	222	3.2	0.006	241
5083–O	All	38	16	16	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5083–H112	All	40	24	12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5086–O	All	35	14	14	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5086–H112	All	35	18	12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Alloy and Temper	Thickness, In.	Minimum Mechanical Properties: Tension			Compression	Shear		Bearing		Buckling Formula Constants: Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B_t	D_t	C_t
5154–O	All	30	11	14	. . .										
5154–H112	All	30	11	12	. . .										
5454–O	Up to 5.000	31	12	14	12					13.5	0.058	142	8.6	0.027	[illegible]
5454–H111	All	34	21	12											
5454–H112	Up to 5.000	31	12	12	12					13.5	0.058	142	8.6	0.027	[illegible]
5454–H311	Up to 5.000	33	20	12	18	19	11	59	34	20.4	0.111	121	12.2	0.051	[illegible]
5456–O	Up to 5.000(1)	42	19	16	19					21.6	0.120	111	13.0	0.056	[illegible]
5456–H111	Up to 5.000(1)	44	26	12				79	44						
5456–H112	Up to 5.000(1)	42	19	12	19					21.6	0.120	111	13.0	0.056	[illegible]
5456–H311	Up to 5.000(1)	42	25	12	22	26	14	79	42	25.3	0.153	106	15.2	0.071	[illegible]
6061–O	All	14	5	16	5	10	3	30	12	5.4	0.015	222	3.2	0.006	[illegible]
6061–T4	All	26	16	16	14	16	9	55	26	15.7	0.074	128	9.4	0.034	[illegible]
6061–T6	All	38	35	10	35	24	20	80	56	38.3	0.202	63	23.0	0.094	[illegible]
6061–T62	All	35	26	10	26	22	15	74	42	28.1	0.127	74	16.9	0.059	[illegible]
6062–O	All	14	5	16	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
6062–T4	All	26	16	16	14	16	9	55	26	15.7	0.074	128	9.4	0.034	[illegible]
6062–T6	All	38	35	10	35	24	20	80	56	38.3	0.202	63	23.0	0.094	[illegible]
6062–T62	All	35	26	10	26	22	15	74	42	28.1	0.127	74	16.9	0.059	[illegible]
6063–T42	Up thru 0.500	17	10	12	10	11	6	36	16	11.0	0.043	149	6.6	0.020	[illegible]
6063–T5	Up thru 0.500	22	16	8	16	13	9	46	25	17.5	0.076	103	10.5	0.036	[illegible]
6063–T6	Up thru 0.124	30	25	8	25	19	14	63	40	28.0	0.155	81	16.8	0.072	10
6063–T6	0.125–0.500	30	25	10	25	19	14	63	40	28.0	0.155	81	16.8	0.072	10
7075–O	All	29	11	10	12	19	6.5	61	26	13.3	0.058	142	8.0	0.027	[illegible]
7075–T6	Up thru 0.249	78	70	7	70	43	40	125	98	79.3	0.602	44	[illegible]	0.280	[illegible]
7075–T6	0.250–0.499	81	73	7	73	45	42	130	102	87.8	0.859	46	[illegible]	0.399	[illegible]
7075–T6	0.500–1.499	82	73	7	73	45	42	131	102	87.8	0.859	46	[illegible]	0.399	[illegible]
7075–T6	1.500–2.999	81	72	7	72	45	42	130	101	81.7	0.629	43	[illegible]	0.292	[illegible]
7075–T6	3.000–4.499(1)	81	71	7	71	45	41	130	99	85.2	0.821	47	[illegible]	0.381	[illegible]
7075–T6	3.000–4.499(2)	78	70	6	70	43	40	125	98	79.3	0.602	44	[illegible]	0.280	[illegible]
7075–T6	4.500–5.000(3)	78	68	6	68	43	39	125	95	76.9	0.575	45	[illegible]	0.267	[illegible]
7178–T6	Up thru 0.249	84	76	5	76	45	44	134	106	86.5	0.686	42	[illegible]	0.319	[illegible]
7178–T6	0.250–2.999(2)	86	78	5	78	46	45	138	109	88.9	0.714	42	[illegible]	0.332	[illegible]

(1) Area up thru 20 sq. in. (2) Area 20 thru 32 sq. in. (3) Area up thru 32 sq. in.

TABLE 4d

Minimum Mechanical Properties and Buckling Formula Constants—Concluded

ROLLED AND COLD-FINISHED ROD AND BAR

See page 39 for explanation of "minimum" properties.
US = ultimate strength in kips per sq in., YS = yield strength in kips per sq in., El = elongation in per cent in 2 in. or 4 dia.
See pages 39 to 41 for definitions, methods of determination and notes.

Alloy and Temper	Diameter or Thickness, In.	Minimum Mechanical Properties								Buckling Formula Constants					
		Tension			Compression	Shear		Bearing		Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B_s	D_s	C_s
2024-O	Up thru 8.000	25	9	16	9	17	5	52	21	9.9	0.037	160	9	0.017	07
2024-T4	Up thru 6.500	62	40	14	40	37	23	118	64	48.0	0.400	77	2. 8	0.186	100
3003-O	All	14	5	25	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
3003-H12	Up thru 0.374	17	12	10	11	11	7	33	19	12.2	0.051	148	7.3	0.023	179
3003-H14	Up thru 0.313	20	17	10	15	13	10	35	28	16.8	0.082	124	10.1	0.038	157
3003-H16	Up thru 0.250	24	21		20	14	12	40	33	22.8	0.131	112	13.7	0.061	144
3003-H18	Up thru 0.204	27	25	.	23	15	14	43	38	26.5	0.164	103	15.9	0.076	131
5052-O	All	25	9.5	25	10	16	5.5	53	20	11.0	0.043	119	6.6	0.020	193
5052-F	0.375 and over	26	11	....	11	17	6.5	55	22	12.2	0.051	148	7.3	0.023	179
6061-O	Up thru 8.000	16	5	18	5	11	3	33	12	5.4	0.015	222	3.2	0.006	241
6061-T4	Up thru 8.000	30	16	18	16	20	9	63	26	18.0	0.072	135	10.8	0.042	152
6061-T6	Up thru 8.000	42	35	10	35	25	20	88	56	38.3	0.202	63	23.0	0.094	82
7075-O	Up thru 8.000	28	11	10	11	18	6.5	59	26	12.2	0.051	148	7.3	0.023	179
7075-T6	Up thru 4.000	77	66	7	66	46	38	123	92	78.7	0.729	49	47.2	0.338	63

TABLE 4e

Minimum Mechanical Properties and Buckling Formula Constants

PIPE

See page 39 for explanation of "minimum" properties.
US = ultimate strength in kips per sq in., YS = yield strength in kips per sq in., El = elongation in per cent in 2 in. or 4 dia.
See pages 39 to 41 for definitions, methods of determination and notes.

Alloy and Temper	Size or Thickness, In.	Minimum Mechanical Properties								Buckling Formula Constants					
		Tension			Compression	Shear		Bearing		Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B_s	D_s	C_s
3003-O	All	14	5	....	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
3003-H112	1 in. and over	14.5	6	....	6	10	3.5	31	14	6.5	0.019	185	3.9	0.009	216
3003-H18	Under 1 in. size	27	24	....	23	15	14	43	38	26.5	0.164	103	15.9	0.076	131
3003-F	1 in. and over	14	5	....	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
6061-T6	Under 1 in. size	42	35	12	35	27	20	88	56	38.3	0.202	63	23.0	0.094	82
6061-T6	1 in. and over	38	35	10	35	24	20	80	56	38.3	0.202	63	23.0	0.094	82
6063-T5	All	22	16	10	16	13	9	46	25	17.5	0.076	105	10.5	0.036	154
6063-T6	All	30	25	8	25	19	14	63	40	28.0	0.155	81	16.8	0.072	105
6063-T832	All	38	35	5	35	23	20	80	56	38.3	0.202	63	23.0	0.094	82

TABLE 4f

Minimum Mechanical Properties and Buckling Formula Constants

EXTRUDED TUBE

See page 39 for explanation of "minimum" properties.

US = ultimate strength in kips per sq in., YS = yield strength in kips per sq in., El = elongation in per cent in 2 in. or 4 dia

See pages 39 to 41 for definitions, methods of determination and notes.

Alloy and Temper	Wall Thickness, In.	Minimum Mechanical Properties: Tension US	Tension YS	Tension El	Compression YS	Shear US	Shear YS	Bearing US	Bearing YS	Buckling Formula Constants: Compression B	Compression D	Compression C	Shear B_t	Shear D_t	Shear C_t
2014-O	All	24	9	12	9	15	5	50	21	9.9	0.037	160	5.9	0.017	20.
2014-T4	0.125-0.499	50	30	12	26	31	17	90	47	30.2	0.200	100	8.1	0.092	12
2014-T4	0.500 and over	55	35	12	30	34	20	99	55	35.2	0.251	89	1.1	0.116	11
2014-T6	0.125-0.499	60	53	7	55	35	31	114	85	61.4	0.410	50	56.8	0.190	61
2014-T6	0.500-0.749	64	58	7	60	37	33	122	93	67.3	0.471	48	60.4	0.219	62
2014-T6	0.750 and over—														
	Area 25 sq in. max.	68	60	7	62	39	35	114	84	69.7	0.196	47	1.8	0.230	6
	Area 25 to 32 sq in.	68	58	6	60	39	33	114	81	67.3	0.471	48	40.4	0.219	62
2024-O	All	25	9	12	9	15	5	52	21	9.9	0.037	160	5.9	0.017	20.
2024-T4	0.499 and less	60	40	10	36	32	23	108	62	41.1	0.275	67	4.7	0.128	8
2024-T4	0.500-1.499	65	46	10	44	34	27	108	71	50.9	0.379	60	0.5	0.176	7
2024-T4	1.500 and over—														
	Area 25 sq in. max.	70	48	10	46	37	28	108	72	53.4	0.407	59	2.0	0.189	7
	Area 25 to 32 sq in.	68	46	6	44	36	27	108	71	50.9	0.379	60	0.5	0.176	7
3003-O	All	14	5	25	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
3003-F	All	14	5		5	10	3	30	12	5.4	0.015	222	3.2	0.006	241

Alloy and Temper	Wall Thickness, In.	Minimum Mechanical Properties: Tension US	Tension YS	Tension El	Compression YS	Shear US	Shear YS	Bearing US	Bearing YS	Buckling Formula Constants: Compression B	Compression D	Compression C	Shear B_t	Shear D_t	Shear C_t
5154-O	All	30	11	14	11	19	6.5	63	23	12.2	0.051	115	7.3	0.023	179
6061-O	All	14	5	16	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
6061-T4	All	26	16	16	14	16	9	54	25	15.7	0.074	128	9.4	0.034	16
6061-T6	All	38	35	10	35	24	20	80	56	38.3	0.202	63	23.0	0.094	8
6062-O	All	14	5	16	5	10	3	30	12	5.4	0.015	222	3.2	0.006	241
6062-T4	All	26	16	16	14	16	9	54	25	15.7	0.074	128	9.4	0.034	16
6062-T6	All	38	35	10	35	24	20	80	56	38.3	0.202	63	23.0	0.094	8
6063-T42	Up to 0.500	17	10	12	10	11	6	36	16	11.0	0.043	149	6.6	0.020	19
6063-T5	Up to 0.500	22	16	10	16	13	9	46	25	17.8	0.076	103	10.5	0.036	13
6063-T6	Up to 0.500	30	25	8	25	19	14	63	40	28.0	0.153	81	16.8	0.072	10
7075-O	All	29	11	10	12	19	6.5	61	26	13.3	0.058	142	8.0	0.027	18
7075-T6	Up to 0.249	78	70	7	70	43	40	125	98	79.3	0.602	44	47.6	0.280	5
7075-T6	0.250-2.999	80	72	7	72	44	42	128	101	81.7	0.629	43	49.0	0.292	5
7178-T6	Up to 0.249	84	76	5	76	45	44	131	106	86.8	0.686	12	51.9	0.319	5
7178-T6	0.250-2.999	86	78	5	78	46	45	138	109	88.9	0.714	12	53.3	0.332	5

TABLE 4h

Minimum Mechanical Properties and Buckling Formula Constants

DIE FORGINGS

See page 39 for explanation of "minimum" properties.
US = ultimate strength in kips per sq in., YS = yield strength in kips per sq in., El = elongation in per cent in 2 in. or 4 dia.
See pages 39 to 41 for definitions, methods of determination and notes.

Alloy and Temper	Thickness, In.	Minimum Mechanical Properties								Buckling Formula Constants					
		Tension			Compression	Shear		Bearing		Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B_s	D_s	C_s
1100-F	Up to 4 in.	11	4	25	4	8	2.5	....	....	4.3	0.010	221	[illegible]	0.005	317
2014-T4	Up to 4 in.	55	30	11	30	34	17	105	48	35.2	0.251	89	21.1	0.116	113
2014-T6	Up to 4 in.	65	55	7	55	39	32	117	88	61.4	0.410	50	3[illegible].8	0.190	64
2018-T61	Up to 4 in.	55	40	7	40	35	23	105	64	48.0	0.400	77	2[illegible].8	0.186	100
2218-T61	Up to 4 in.	55	40	7	40	35	23	105	64	48.0	0.400	77	2[illegible].8	0.186	100
2218-T72	Up to 4 in.	38	29	6	29	24	17	72	46	33.9	0.237	91	20.3	0.110	118
3003-O	All	14	5	25	5	10	3	30	12	5.4	0.015	222	[illegible]2	0.006	341
3003-F	All	14	5		5	10	3	30	12	5.4	0.015	222	[illegible]2	0.006	341
4032-T6	Up to 4 in.	52	42	3	42	36	24	....	....	50.6	0.433	75	30.4	0.202	100
6061-T6	Up to 4 in.	38	35	7	35	25	20	80	56	38.3	0.202	65	2[illegible].0	0.094	82
6151-T6	Up to 4 in.	44	37	10	37	28	21	92	59	40.6	0.220	61	24.4	0.103	79
7075-T6	Up to 3 in.	75	65	7	65	45	37	120	97	73.3	0.535	[illegible]	4[illegible].0	0.249	[illegible]
7079-T6	Up to 6 in.	74	64	7	64	43	37	119	96	72.1	0.522	[illegible]	4[illegible].3	0.243	[illegible]

TABLE 4i

Minimum Mechanical Properties and Buckling Formula Constants

SAND CASTINGS

See page 39 for explanation of "minimum" properties.
US = ultimate strength in kips per sq in., YS = yield strength in kips per sq in., El = elongation in per cent in 2 in. or 4 dia.
See pages 39 to 41 for definitions, methods of determination and notes.

Alloy and Temper	Thickness, In.	Minimum Mechanical Properties								Buckling Formula Constants					
		Tension			Compression	Shear		Bearing		Compression			Shear		
		US	YS	El	YS	US	YS	US	YS	B	D	C	B_s	D_s	C_s
43-F	The values to the right are based on tests of standard specimens individually cast. See page 41.	17	7	3	7	12	....	....	....	7.0	0.025	186	4.6	0.011	212
122-T61		30	28	+	30	22	....	....	....	35.2	0.251	89	21.1	0.116	113
142-T21		23	14	+	14	17	....	....	....	15.7	0.074	128	9.4	0.034	162
142-T571		29	26	+	30	23	....	....	....	35.2	0.251	89	21.1	0.116	113
142-T77		21.5	15	+	16	16	....	....	....	18.0	0.092	128	10.8	0.042	152
195-T4		29	13	6	14	22	....	61	26	15.7	0.074	128	9.4	0.034	162
195-T6		32	20	3	21	24	....	67	40	21.0	0.141	107	14.4	0.065	154
195-T62		36	28	+	29	28	....	76	56	33.9	0.237	91	20.3	0.110	118
195-T7		29	16	3	17	21	....	61	32	19.2	0.101	120	11.5	0.047	163
214-F		22	9	6	10	17	....	....	....	11.0	0.013	149	6.6	0.020	193
B214-F		17	10	+	11	13	....	....	....	12.2	0.031	118	7.3	0.023	179
F214-F		17	9	+	10	13	....	....	....	11.0	0.013	149	6.6	0.020	193

Continued on next page

HAIGHT, GARDNER, POOR & HAVENS
FEDERAL BAR BUILDING
1819 H STREET, N. W.
WASHINGTON, D. C. 20006
CABLE: MOTOR WASHINGTON
WU: TELEX 892598
TELEPHONE (202) 737-7847

April 18, 1980

APR [illegible] 1980

BY HAND

Oren R. Lewis, Jr., Esq.
Lewis, Wilson, Lewis & Jones
2054 North 14th Street
Arlington, Virginia 22216

FFAC v. Lockheed Aircraft Corporation
Our file 2041-1278-2B

Zimmerly v. Lockheed Aircraft Corporation
Our file 2041-1278-5B

Dear Oren:

Pursuant to plaintiffs' Notice to Produce Physical Evidence at Trial and subpoena thereon and defendant's Motion to Quash that subpoena and notice, we appeared before the Court on Tuesday, April 15, 1980 to move to quash that subpoena. The judge extended the subpoena through the end of this week and asked that a report be given by Friday of this week on the documents requested in the Notice to Produce.

With respect to those categories, the judge has already ruled in the negative denying requests as to categories (6) and (8). As to the following categories we make the following production:

(1) We hereby provide seven black-and-white slides not pertaining to the crash scene and therefore they are not within your request for production in the surviving orphans cases. These slides appear to have to do with the ramp portion and ramp locking system of the aircraft and do not appear to be taken at the scene of the crash. Nevertheless, we are making them available to you for your review in Court so that if you

wish copies made of them you should advise us and we will do so.

(2) Lockheed has no such documents pertaining to autopsies, death certificates, etc. except those produced by the government.

(3) The Collateral Investigation was conducted solely by the Air Force and Lockheed has no documents relating thereto except the Collateral Report itself, which has previously been produced to plaintiffs' counsel.

(4) Except for the document prepared by Lockeed with respect to G-forces which has previously been listed as within attorney work product and except as to G-forces information contained in MADAR data already produced or produced today and John Edwards' formula for G-forces as to which Mr. Edwards was prepared to testify at trial but was not requested to do so, defendant knows of no other documents relating to G-forces generated on or in C-5A 68-218.

(5) Defendant is making available to plaintiff a magnetic tape copy of the MADAR tape from AF 68-218; a total "dumpout" in octal form prepared at the request of trial counsel last week in light of plaintiffs' inquiries concerning MADAR data; and eight pages of computation made by Lockheed from MADAR data on AF 68-218 on April 4, 1975 which we may have already given to you. All other documentation in defendant's possession with respect to MADAR on the April 4, 1975 AF 68-218 flight in issue herein has been produced to defendant's knowledge.

(7) Defendant is making available for inspection at our offices or use in Court only a model of the C-5A aircraft and the model of the C-5A used in the wind-tunnel test conducted by Professor Harper as previously agreed in Court on April 15, 1980.

(9) Other than documents already produced, defendant knows of no documents pertaining to

(a) the manner in which C-5A 68-218 broke apart after the second impact on April 4, 1975 near Saigon, South Vietnam;

(b) the nature of the forces and the expenditure of energy associated with such break-up of C-5A 68-218;

(c) the manner in which a C-5A would break up upon a crash landing; and

(d) the nature of the forces in the expenditure of energy associated with the break-up of a C-5A upon a crash landing.

As to categories (c) and (d) defendant knows of no Lockheed documents pertaining to same but is continuing its inquiry.

Sincerely yours,

Carroll E. Dubuc

Enclosures

cc: Honorable Louis F. Oberdorfer
James P. Piper, Esq.

TIME	VA/CG	LAT/CG
5:28:49.55	0.52 MIN	-0.37 * MIN
.60	0.16 * (.54)	0.01
.65	1.01	0.38
.70	NR	0.03 ~~0.02~~
.75	0.40	0.18
.80	0.61 MAX	-0.04
.85	1.37 * (.37)	0.13
.90	NR	0.23
.95	0.99	0.28
5:28:50.00	0.55	0.45* MAX
.05	NR	0.40
.10	0.39	0.27
.15	0.54	0.12 ~~0.23~~
.20	0.77	0.15
.25	1.18	NR
.30	NR	0.25
.35	0.85	0.12
.40	0.53	0.05
.45	0.70	0.23
.50	0.98	0.29
.55	1.17	0.13
.60	1.21	0.10
.65	NR	0.26
.70	1.17	0.30
.75	1.03	0.24
.80	0.96	0.30
.85	1.25	0.27 NOT SHOWN -0.24 +0.16

TIME	VA/CG	LAT/CG
.95	1.13	NR
5:28:51.00	1.05	0.09
.05	0.95	0.18
.10	1.03 ~~1.35~~	0.15 ~~0.15~~
.15	NR	NR
.20	NR	0.20
.25	0.98 ~~1.01~~	0.16
.30	1.05	NR
.35	0.91	0.05
.40	NR	0.14
.45	1.02	0.24
.50	NR	0.17
.55	1.06	NR
.60	NR	0.13
.65	0.96	NR
.70	0.92	NR
.75	0.96	NR
.80	NR	NR
.85	1.07	0.10
.90	NR NOT SHOWN	NR ON [illegible]
.95	0.95	NR
5:28:52.00	NR	NR

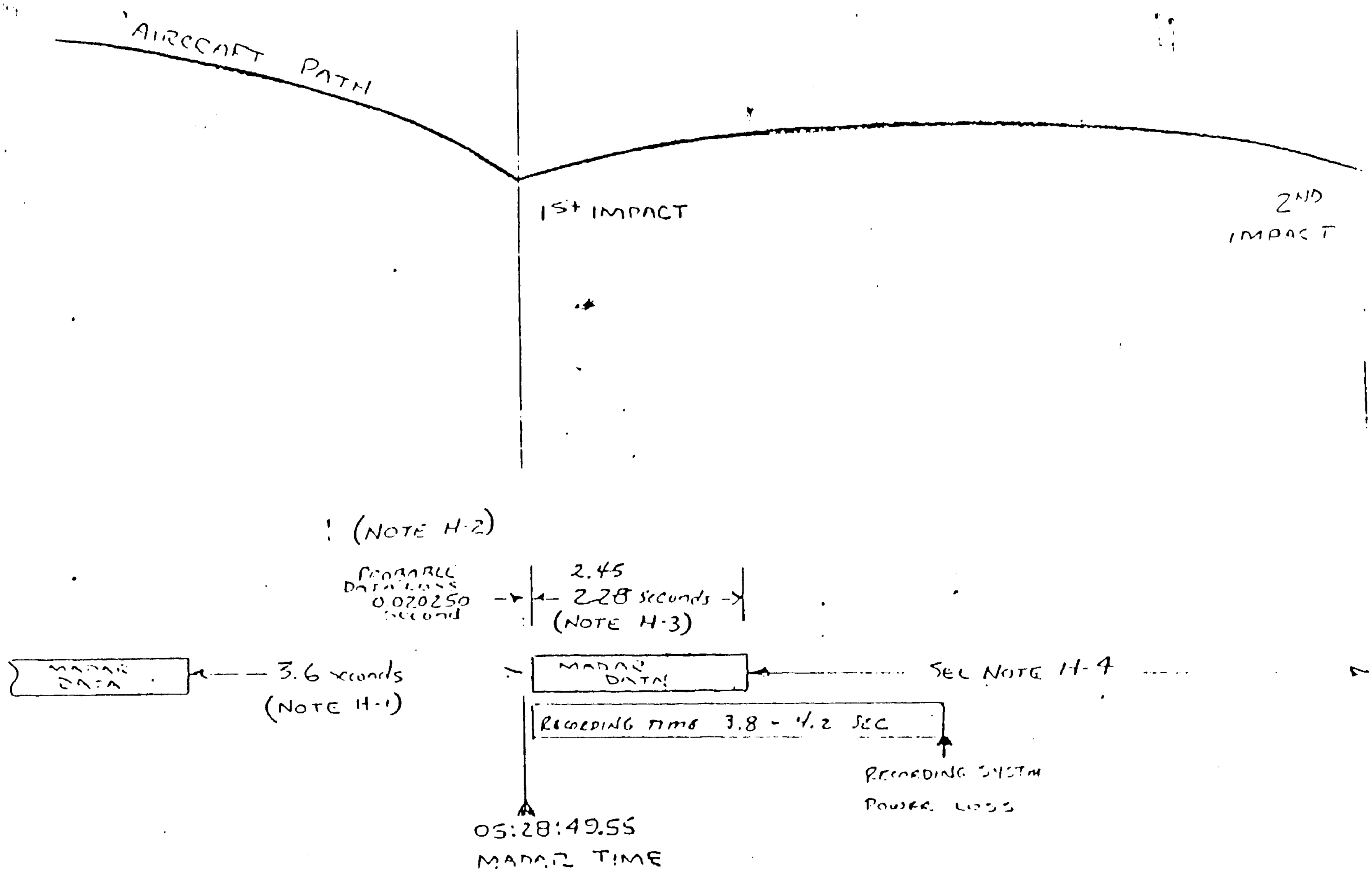
DECODING OF SLRP (05) MESSAGES ON RECORD 11977

LOCKHEED-GEORGIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

OCTAL X_1X_2	X_3X_4	X_5X_6	X_7X_8	X_9X_{10}	(X_3X_4) HEX	CONV DEC	SEC/10	(X_5X_6) HEX	CONV DEC	X_7 HEX	PCODE	X_8 HEX	DEC	(X_9X_{10}) HEX	CONV DEC	COUNTS	ENGINEERING INTERPRETATION	PARAMETER
05	34	54	16	24	1C	14	.14	2C	22	0	44	E	14	14	10	-22	22, DISENGAGED	INFLIGHT REFUEL.
05	34	42	56	12	1C	14	14	22	17	2	35	E	14	0A	5	-27	-0.027 RAD/SEC²	PITCH ACCELERAT.
05	36	14	16	22	1E	15	15	0C	6	0	12	E	14	12	9	-23 ✓	1.03 G'S	VA/CG
05	36	12	24	34	1E	15	15	0A	5	1	10	4	4	1C	14	78 ✓	0.24 G'S	LAT/CG
05	36	42	62	04	1E	15	15	22	17	3	35	2	2	04	2	34	0.034 RAD/SEC²	PITCH ACCELERATIO.
05	40	14	16	02	20	16	16	0C	6	0	12	E	14	02	1	-31 ✓	0.96 G'S	VA/CG
05	40	12	26	17	20	16	16	0A	5	1	10	6	6	0F	0	96 ✓	0.30 G'S	LAT/CG
05	40	06	02	40	20	16	16	06	3	0	6	2	2	20	16	-208	537 FT	PRESS ALTITUDE
05	40	42	62	34	20	16	16	22	17	3	35	2	2	1C	14	46	0.046 RAD/SEC²	PITCH ACCELERA:
05	42	14	20	17	22	17	17	0C	6	1	12	0	0	0F	0	0 ✓	1.25 G'S	VA/CG
05	42	12	24	14	22	17	17	0A	5	1	10	4	4	0C	6	70 ✓	0.22 G'S	LAT/CG
05	42	56	20	64	22	17	17	2E	23	1	46	0	0	34	26	-26	-26, NOT DEPLOY	AIR DROP
05	42	42	56	64	22	17	17	22	17	2	35	E	14	36	27	-5	-0.005 RAD/SEC²	PITCH ACCELERAT.
05	44	12	72 (22)	50	24	18	18	0A	5	0 (1)	10	A (2)	10 (2)	28	20	-265	±0.24 (.16) G'S	LAT/CG
05	44	60	16	74	24	18	18	30	24	0	48	E	14	3C	30	-2	+2, UNKNEELED	FORWARD KNEEL
05	44	42	52	32	24	18	18	22	17	2	35	A	10	1A	13	-103	-0.103 RAD/SEC²	PITCH ACCELERA
05	46	14	16	46	26	19	19	0C	6	0	12	E	14	26	19	-13 ✓	1.13 G'S	VA/CG
05	46	10	14	12	26	19	19	08	4	0	8	C	12	0A	5	-59	0.41	MACH NO.
05	46	42	46	56	26	19	19	22	17	2	34	6	6	2E	23	-137	137, RETRACTED	GROUND SPOILER
05	50	14	16	26	28	20	20	0C	6	0	12	E	14	16	11	-21 ✓	1.05 G'S	VA/CG
05	50	12	20	74	28	20	20	0A	5	1	10	0	0	3C	30	30 ✓	0.09 G'S	LAT/CG
05	50	62	16	74	28	20	20	32	25	0	50	E	14	3C	30	-2	2, UNKNEELED	LEVEL KNEEL
CLOCK MESSAGE					27175262 46			SKIP TO NEXT SLRP MESSAGE (05 FLAG).										
05	02	14	16	17	02	1	1	0C	6	0	12	E	14	0F	0	-32 ✓	0.95 G'S	VA/CG
05	02	12	22	62	02	1	1	0A	5	1	10	2	2	32	25	57 ✓	0.18 G'S	LAT/CG
05	02	42	50	70	02	1	1	22	17	2	35	8	8	38	28	-100	-0.100 RAD/SEC²	PITCH ACCELERAT.
05	04	14	16	22	04	2	2	0C	6	0	12	E	14	12	9	-23 9	1.33 G'S	VA/CG
05	04	12	22	21 (42)	04	2	2	0A	5	1	10	2	2	14 (12)	10 (9)	48 42	0.13 (0.15) G'S	LAT/CG
05	04	42	54	46	04	2	2	22	17	2	35	C	12	26	19	-45	-0.045 RAD/SEC²	PITCH ACCELERATI.
05	06	42	56	66	06	3	3	22	17	2	35	E	14	36	27	-5	-0.005 RAD/SEC²	PITCH ACCELERA
05	10	12	20	04	08	4	4	0A	5	1	10	4	4	04	2	66 ✓	0.20 G'S	LAT/CG

LOCKHEED-GEORGIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

OCTAL x_1x_2 x_3x_4 x_5x_6 x_7x_8 x_9x_{10}	(x_3x_4) HEX	CONV DEC	SEC/20	(x_5x_6) HEX	CONV DEC	x_7 HEX	P CODE	x_8 HEX	DEC	(x_9x_{10}) HEX	CONV DEC	COUNTS	ENGINEERING INTERPRETATION		PARAMETER
05 10 42 60 30	08	4	4	22	17	3	35	0	0	18	12	12	0.012	RAD/SEC²	PITCH ACCELERAT
05 12 14 16 06	0A	5	5	0C	6	0	12	E	14	35	6	-26 -27	0.98 1.04	G'S	VA/CG
05 12 12 22 52	0A	5	5	0A	5	1	10	2	2	2A	21	53✓	0.16	G'S	LAT/CG
05 14 14 16 26	0C	6	6	0C	6	0	12	E	14	16	11	-21✓	1.05	G'S	VA/CG
05 14 30 26 44	0C	6	6	18	12	1	24	6	6	24	18	114	-14.7	DEG	RT AILERON POS
05 16 14 14 70	0E	7	7	0C	6	0	12	C	12	38	28	-36✓	0.91	G'S	VA/CG
05 16 12 20 62	0E	7	7	0A	5	1	10	0	0	32	25	25✓	0.08	G'S	LAT/CG
05 20 12 22 30	10	8	8	0A	5	1	10	2	2	18	12	44✓	0.14	G'S	LAT/CG
05 22 14 16 16	12	9	9	0C	6	0	12	E	14	0E	7	-25✓	1.02	G'S	VA/CG
05 22 12 24 34	12	9	9	0A	5	1	10	4	4	1C	14	78✓	0.24	G'S	LAT/CG
05 22 42 60 54	12	9	9	22	17	3	35	0	0	2C	22	22	0.022	RAD/SEC²	PITCH ACCELERA
05 24 12 22 60	14	10	10	0A	5	1	10	2	2	30	24	56✓	0.17	G'S	LAT/CG
05 26 14 16 30	16	11	11	0C	6	0	12	E	14	18	12	-20	1.06	G'S	VA/CG
05 26 42 56 74	16	11	11	22	17	2	35	E	14	3C	30	-2	-0.002	RAD/SEC²	PITCH ACCELERA
05 30 14 16 16	18	12	12	0C	6	0	12	E	14	0E	7	-25✓	1.02	G'S	VA/CG
05 30 12 22 24	18	12	12	0A	5	1	10	2	2	14	10	42✓	0.13	G'S	LAT/CG
05 30 42 56 42	18	12	12	22	17	2	35	E	14	22	17	-15	-0.015	RAD/SEC²	PITCH ACCELERA
05 32 14 16 02	1A	13	13	0C	6	0	12	E	14	02	1	-31✓	0.96	G'S	VA/CG
05 34 14 14 72	1C	14	14	0C	6	0	12	C	12	3A	29	-35✓	0.92	G'S	VA/CG
05 36 14 16 02	1E	15	15	0C	6	0	12	E	14	02	1	-31✓	0.96	G'S	VA/CG
05 40 30 26 60	20	16	16	18	12	1	24	6	6	30	24	120	-15.2	DEG	RT AILERON PO
05 40 06 20 44	20	16	16	06	3	1	6	0	0	24	18	18	25616	FT	PRESS ALTITU
05 42 14 16 32	22	17	17	0C	6	0	12	E	14	1A	13	-19✓	1.07	G'S	VA/CG
05 42 12 22 17	22	17	17	0A	5	1	10	2	2	0F	0	32✓	0.10	G'S	LAT/CG
05 42 42 56 06	22	17	17	22	17	2	35	E	14	06	3	-29	-0.029	RAD/SEC²	PITCH ACCELERA
05 46 14 16 17	26	19	19	0C	6	0	12	E	14	0F	0	-32	0.95	G'S	VA/CG
CLOCK MESSAGE	27 17 52 64 50														



AIRCRAFT PATH
1st IMPACT
2ND IMPACT
(NOTE H-2)
0.020250
2.45
2.28 seconds
(NOTE H-3)
RADAR DATA
3.6 seconds
(NOTE H-1)
RADAR DATA
SEE NOTE H-4
RECORDING TIME 3.8 - 4.2 SEC
RECORDING SYSTEM POWER LOSS
05:28:49.55
RADAR TIME

1. $D = VT$. D = distance
V = Velocity (when V_2 ...
t = time.

2. $D = \frac{V_1 + V_2}{2} T$ for a Velocity that changes

3. $D = \frac{V_1}{2} \cdot T$ If V_2 is 0 as was the case

4. $T = \frac{2D}{V}$

Also $D = \frac{1}{2} A T^2$

5. Or $A = \frac{2D}{T^2}$

substituting #4 into #5

6. $A = \frac{2D}{\left(\frac{2D}{V}\right)^2} = \frac{2D}{\frac{4D^2}{V^2}}$

$A = \frac{2D}{4D^2} \times V^2$.

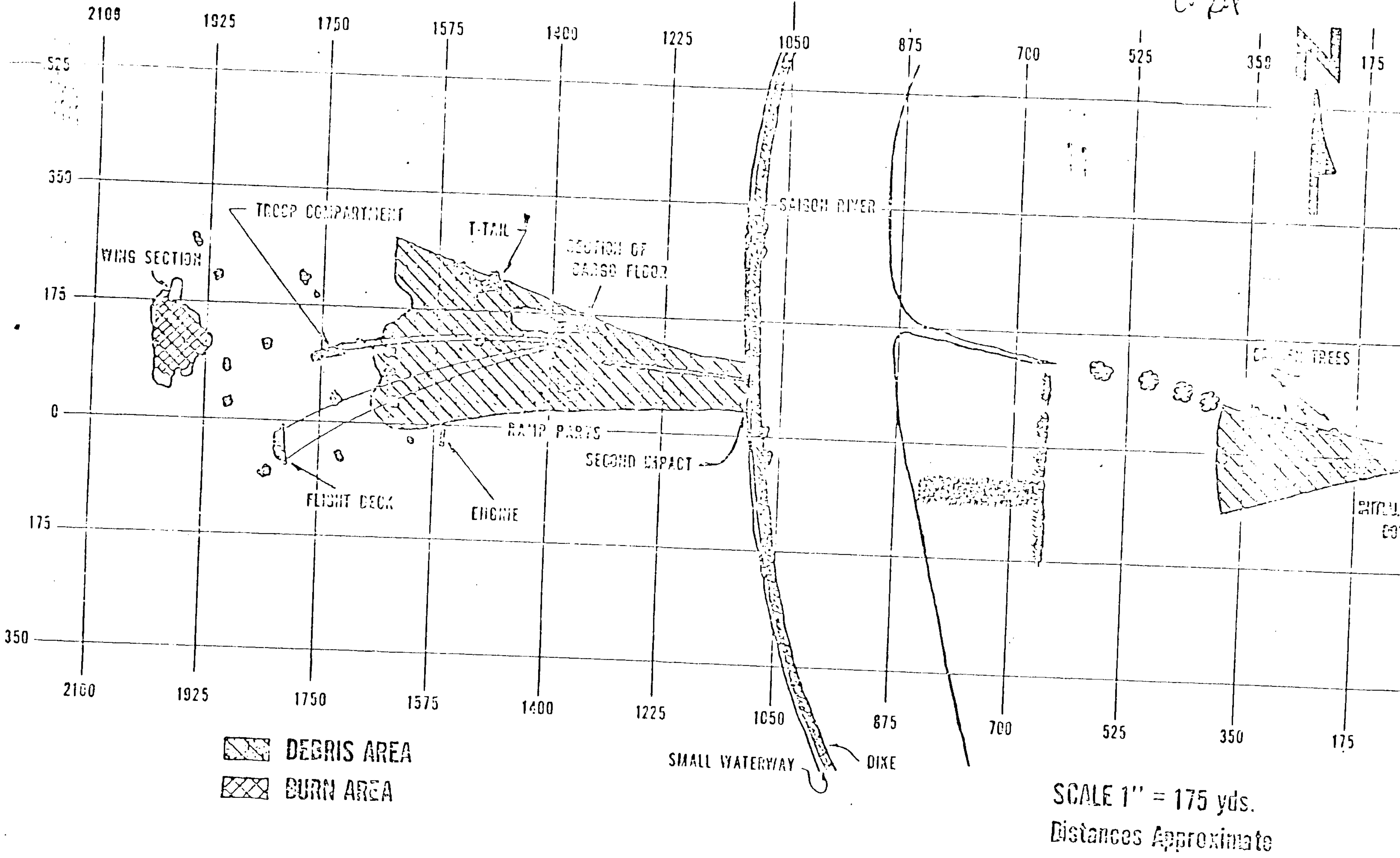
$A = \frac{V^2}{2D}$

7. If g's are desired you divide A by 32.2

$\left(\frac{A}{32.2}\right) = \frac{V^2}{2D \times 32.2}$

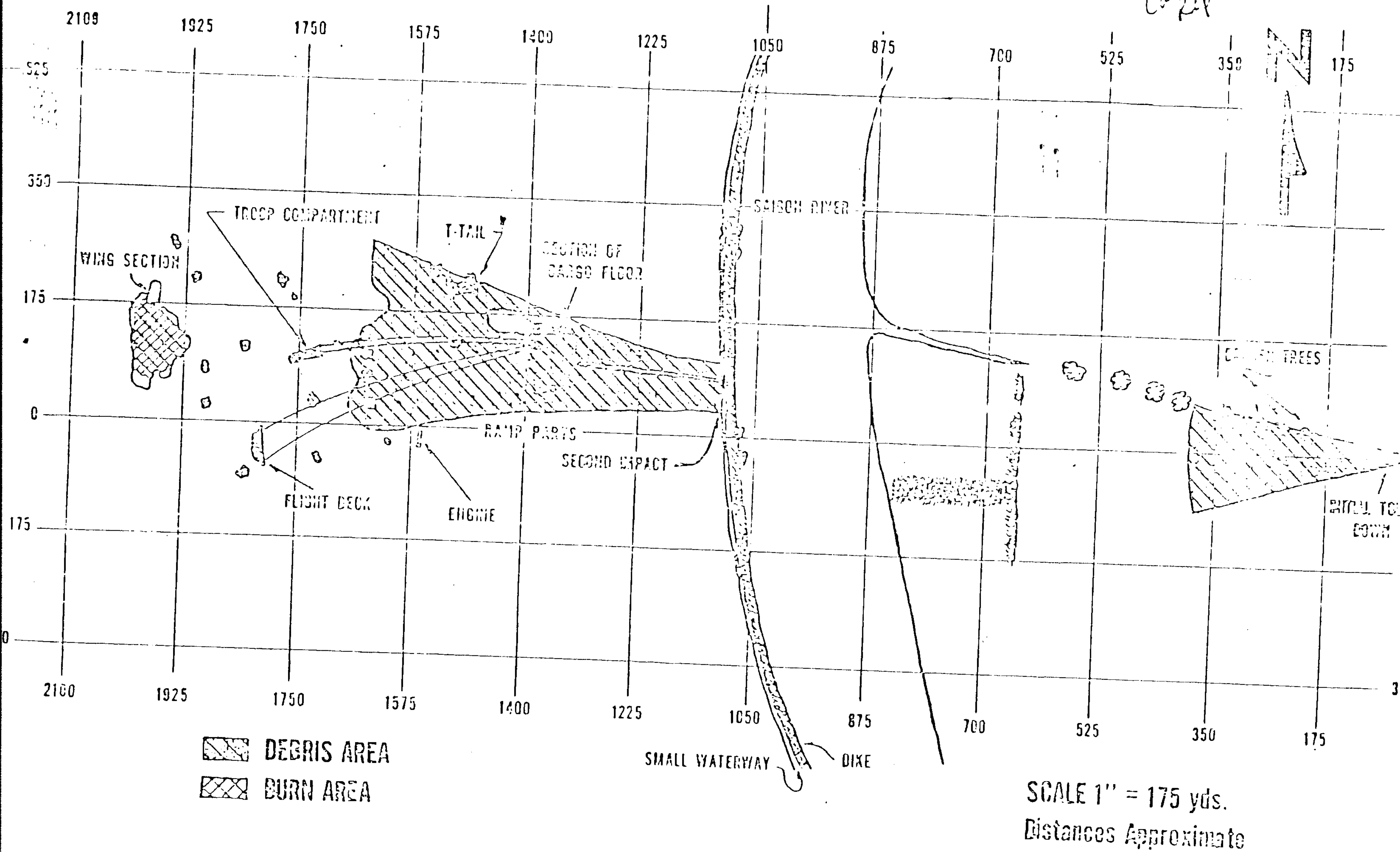
WRECKAGE DIAGRAM

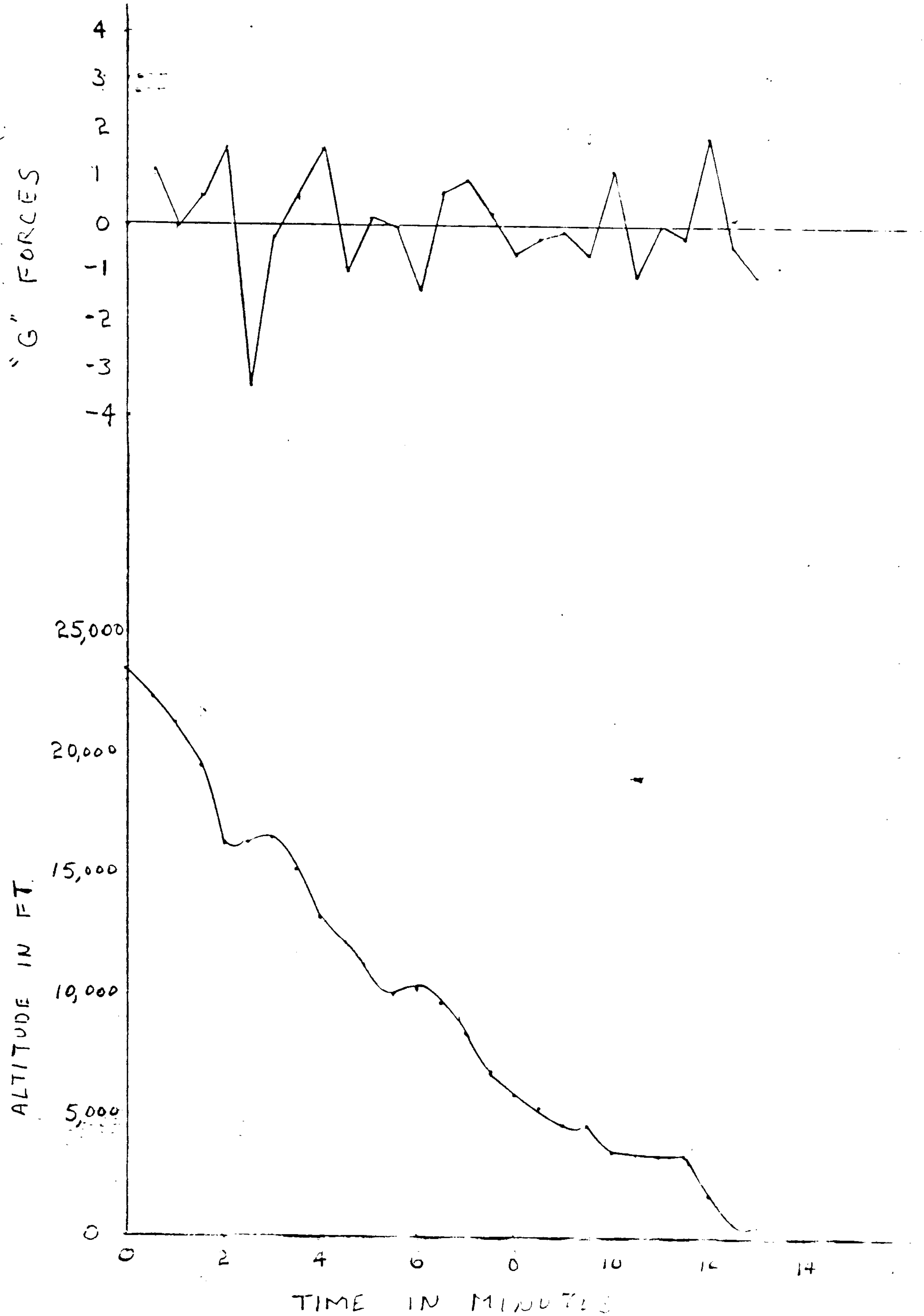
C-5A SN 68-218 4 APRIL 1975



WRECKAGE DIAGRAM

C-5A SN 68-218 4 APRIL 1975





ZERO TIME IS INITIAL DECENT AFTER DECOMPRESSIO

TIME (MIN)	ALTITUDE FT	ΔH FT	$\frac{\dot{\Delta} H}{\Delta t}$	$\frac{\Delta^2 H}{\Delta t^2}$	CALCULATED VERTICAL g FORCE
0	23,424	0.0	0		
0.5	22,313	-1111.0	-37.03	+37.03	1.15
1.0	21,202	-1111.0	-37.03	0.0	[illegible]
1.5	19,535	-1667.0	-55.57	+18.54	0.58
2.0	16,313	-3222.0	-107.40	+51.83	1.61
2.5	16,313	- 0.0	0	-107.4	-3.[illegible]4
3.0	16,536	+223.0	+7.43	+7.43	-[illegible]3
3.5	15,202	-1334.0	-11.13	+18.56	0.58
4.0	13,314	-1888.0	-62.93	+51.80	1.61
4.5	12,314	-1000.0	-33.33	+29.60	-0.92
5.0	—	-1107.5	-36.92	+3.59	0.11
5.5	10,099	-1107.5	-36.92	0	0.0
6.0	10,314	+215.0	+7.17	-44.09	-1.37
6.5	9,870	-444.0	-14.80	+21.97	0.66
7.0	8,536	-1334.0	-44.47	+29.67	0.92
7.5	6,981	-1555.0	-51.83	+7.36	0.23
8.0	5,981	-1000.0	-33.33	-18.50	-0.5[illegible]
8.5	5,315	-660.0	-22.00	-11.33	-0.35
9.0	4,759	-555.0	-18.50	-3.50	-0.1
9.5	4,759	0.0	0.0	-18.50	-0.58
10.0	3,648	-1111.0	-37.03	+37.03	1.15
10.5	3,537	-111.0	-3.70	-33.33	-1.04
11.0	3,426	-111.0	-3.70	0.0	0.0
11.5	3,537	+111.0	+3.70	-7.40	-[illegible]
12.0	1,870	1667.0	-55.57	+59.27	1.84
12.5	648	1222.0	-40.73	-14.84	-0.46
13.0	537	111.0	-3.70	-37.03	-1.15

*051236	22312	0.576	
051239	22423	0.598	5:12:35 TO 5:12:41
*051244	22535	—	
051252	22646	0.602	5:12:42 TO 5:12:52
*051256	22757		
*051300	22868	—	← FLIGHT
051304	22979	0.604	
051314	23201	0.610	5:13:10 - 5:13:17
051329	23423.297	—	5:13:29 ← 5:13:30 ALTITUDE
051348	23313	0.620	5:13:42 5:13:49
051353	22979	0.638	5:13:50 5:13:56
051358	22757	0.648	5:13:57 5:14:02
*051404	22535	0.656	
*051407	22423	0.658	
051411	22313	0.664	5:14:12 5:14:16
*051417	22090	0.672	
051422	21868	0.680	5:14:18 5:14:23
051427	21757	0.682	5:14:24 5:14:29
051433	21646	0.674	5:14:30 5:14:34
051423	21535	0.668	
051443	21424	0.654	5:14:36 5:14:43
051449	21202	0.648	5:14:44: 5:14:51
*051453	21090	0.646	
051459	20868.5	0.640	5:14:52 5:14:59
051504	20646	0.620 (?)	5:15:0 5:15:7
*051508	20313	—	
051512	20011	0.632	5:15:8 5:15:13
051516	19535	0.626	5:15:14 5:15:18
051529	18535	0.634	5:15:25 5:15:31
05152[illegible]			

*051608	16202	—		
051612	16091	0.658	5:16:6	5:16:12
051629	16313	0.582	5:16:22	5:16:33
*051635	16758	0.550		
051640	16980	0.528	5:16:34	5:16:41
051645	17091	0.514 ←	5:16:43	5:16:57
*051716	16757.8	0.510		
051721	16536	0.518	5:17:15	5:17:22
051730	16202	0.524	5:17:23	5:17:30
*051734	16091	0.528		
051739	15980	0.530	5:17:31	5:17:40
*051743	15869	0.532	B	
051748	15647	0.536	5:17:41	5:17:50
051758	15313.5	0.530	5:17:51	5:17:58
051804	15202	—	5:17:59	5:18:6
051810	14980	0.526	5:18:7	5:18:14
*051815	14869	0.518		
051820	14758	0.508	5:18:15	5:18:24
051830	14313.6	0.502	31:23:46	5:18:34
*051834	14091	—		
051851	13314	0.498	21:20:46	5:18:52
051857	12980	0.504	5:18:53	5:19:0
051904	12758	0.508	5:19:1	5:19:9
*051910	12536	0.510		
051914	12424	—	5:19:10	5:19:16
051925	12314	0.496	5:19:25	5:19:31
051935	12203	0.488	5:19:32	5:19:41
*051944	12092	0.478		
051948	11980.5	0.476	5:19:42	5:19:49
051952	11869	0.474	5:19:51	5:19:57

052030	10758	0.474
*052305	10536	0.480
052042	10314	0.486
052053	10092	0.490
*052111	9980.7	0.466
052117	9869.6	0.468
052129	10091.8	0.460 ←
052135	10314	0.452
052149	10758	0.438
052156	10869.5	0.414
052207	10758	0.406
052212	10314	0.410
052219	9869.6	0.442
*052225	9425	0.468
052231	9092	0.476
052237	8870	0.472
052243	8758.6	0.462
*052250	8536.4	0.446

5:20:27	5:20:34
5:20:35	5:20:42
5:20:52	5:21:0
5:21:10	5:21:17
5:21:26	5:21:32
5:21:34	5:21:39
5:21:46	5:21:52
5:21:53	5:21:59
5:22:0	5:22:7
5:22:8	5:22:16
5:22:17	5:22:24
5:22:25	5:22:32
5:22:33	5:22:38
5:22:39	5:22:43

05 22 50
08 13 60

5:1:23	5:1:25	—	0.172
5:1:26	5:1:28	—	0.172
5:1:29	5:1:32	—	0.204
5:1:33	5:1:35	537.20	0.216
5:1:36	5:1:39	537.20	0.234
5:1:40	5:1:44	648.30	0.246
5:1:45	5:1:49	648.30	0.246
5:1:50	5:1:53	870.50	0.256
5:1:54	5:1:59	981.60	0.258
5:2:0	5:2:5	1203.80	0.264
5:2:7	5:2:9	1426.00	0.266
5:2:10	5:2:13	1648.20	0.272
5:2:14	5:2:20	1870.40	0.272
5:2:21	5:2:27	2425.90	0.276
5:2:28	5:2:35	2759.20	0.276
5:2:36	5:2:43	3203.60	0.284
5:2:44	5:2:52	3536.90	0.296
5:2:53	5:3:1	3870.20	0.314
5:3:8	5:3:11	4314.60	0.326
5:3:12	5:3:20	4647.90	0.332
5:3:21	5:3:30	5092.30	0.330
5:3:31	5:3:38	5536.70	0.340
5:3:39	5:3:45	5647.80	0.342
5:3:46	5:3:52	5981.10	0.350
5:3:53	5:4:2	6425.50	0.360
5:4:3	5:4:13	7092.10	0.364
5:4:14	5:4:22	7647.60	0.372
5:4:23	5:4:32	7980.90	0.378
5:4:33	5:4:43	8314.20	0.378
5:6:2	5:6:5	8314.20	0.378
5:5:6	5:5:16	9869.60	0.390
5:5:17	5:5:27	10091.80	0.406

5:5:38	5:5:49	10969.50	0.430
5:5:50	5:6:0	11536.10	0.434
5:6:1	5:6:11	11869.40	0.432
5:6:12	5:6:22	12313.80	0.438
5:6:23	5:6:33	12758.70	0.446
5:6:34	5:6:43	12980.40	0.456
5:6:55	5:6:57	13535.90	0.452
5:7:38	5:7:48	15091.30	0.478
5:7:50	5:7:59	15202.40	0.484
5:8:0	5:8:13	15646.80	0.494
5:8:14	5:8:23	15980.10	0.502
5:8:24	5:8:35	16535.60	0.502
5:8:36	5:8:48	16868.90	0.502
5:8:49	5:8:59	17091.10	0.506
5:9:1	5:9:10	17535.50	0.506
5:9:11	5:9:21	17979.90	0.506
5:9:22	5:9:27	18202.10	0.506
5:9:34	5:9:45	18535.40	0.512
5:9:46	5:9:57	18868.70	0.522
5:9:58	5:10:8	19090.90	0.530
5:10:9	5:10:21	19424.20	0.536
5:10:22	5:10:31	19757.50	0.540
5:10:33	5:10:42	20090.80	0.542
5:10:43	5:10:54	20424.10	0.542
5:11:7	5:11:14	20424.10	0.542
5:11:15	5:11:25	20979.60	0.544
5:11:26	5:11:36	21312.90	0.554
*9:30:11	4:62:40	21312.90	0.554
5:12:7	5:12:17	21979.50	0.590
5:12:18	5:12:22	22090.60	0.590
5:12:23	5:12:26	22201.70	0.594
5:12:27	5:12:34	22201.70	0.594

5:13:1	5:13:9	22979.40	0.608
5:13:10	5:13:17	23201.60	0.610
5:13:18	5:13:19	23201.60	0.610
*5:13:20	7:63:63	23201.60	0.610
*2:16:22	5:13:27	23201.60	0.610
5:13:28	5:13:34	23423.80	0.606
5:13:35	5:13:41	23423.80	0.600
5:13:42	5:13:49	23312.70	0.620
5:13:50	5:13:56	22979.40	0.638
5:13:57	5:14:2	22757.20	0.648
5:14:3	5:14:11	22312.80	0.664
5:14:12	5:14:16	22312.80	0.664
5:14:18	5:14:23	21868.40	0.680
5:14:24	5:14:29	21757.30	0.682
5:14:30	5:14:34	21646.20	0.674
5:14:36	5:14:43	21424.00	0.654
5:14:44	5:14:51	21201.80	0.648
5:14:52	5:14:59	20868.50	0.640
5:15:0	5:15:7	20646.30	0.634
5:15:8	5:15:13	20090.80	0.632
5:15:14	5:15:18	19535.30	0.626
5:15:19	5:15:24	18979.80	0.630
5:15:25	5:15:31	18535.40	0.634
5:15:32	5:15:39	18313.20	0.634
5:15:40	5:15:47	17313.20	0.640
*5:15:48	17:32:31	17313.20	0.640
5:15:56	5:16:1	16646.70	0.656
5:16:2	5:16:5	16313.40	0.660
5:16:6	5:16:12	16091.20	0.658
5:16:13	5:16:18	16091.20	0.648
5:16:19	5:16:23	16091.20	0.648
5:16:24	5:16:28	16091.20	0.620

5:16:52	5:16:58	17091.10	0.500
*5:17:2	5:17:2	17091.10	0.500
5:17:15	5:17:22	16535.60	0.518
5:17:23	5:17:30	16202.30	0.526
5:17:31	5:17:40	15980.10	0.530
5:17:41	5:17:50	15646.80	0.536
5:17:51	5:17:58	15313.50	0.530
5:17:59	5:18:6	15202.40	0.530
5:18:7	5:18:14	14980.20	0.526
5:18:15	5:18:24	14758.00	0.508
*31:23:46	5:18:34	14313.60	0.502
5:18:35	5:18:40	13980.30	0.502
*21:20:46	5:18:52	13313.70	0.498
5:18:53	5:19:0	12980.40	0.504
5:19:1	5:19:9	12758.20	0.508
5:19:10	5:19:16	12424.90	0.510
5:19:17	5:19:24	12424.90	0.504
5:19:25	5:19:31	12313.80	0.494
5:19:32	5:19:41	12202.70	0.482
5:19:92	5:19:49	11980.50	0.476
5:19:51	5:19:59	11869.40	0.472
5:20:0	5:20:8	11647.20	0.472
5:20:10	5:20:16	11647.20	0.472
5:20:20	5:20:26	10980.60	0.472
5:20:27	5:20:34	10758.40	0.474
5:20:35	5:20:42	10314.00	0.486
5:20:43	5:20:51	10314.00	0.490
5:20:52	5:21:0	10091.80	0.480
5:21:1	5:21:8	10091.80	0.470
5:21:10	5:21:17	9869.60	0.468
5:21:18	5:21:25	9869.60	0.470
5:21:26	5:21:32	10091.80	0.460

5:21:53	5:21:59	10869.50	0.414
5:22:0	5:22:7	10758.40	0.406
5:22:8	5:22:16	10314.00	0.410
5:22:17	5:22:24	9869.60	0.442
5:22:25	5:22:32	9091.90	0.476
5:22:33	5:22:38	8869.70	0.476
5:22:39	5:22:43	8758.60	0.462
5:22:44	5:22:49	8758.60	0.462
5:22:50	5:22:56	8425.30	0.434
5:22:58	5:22:59	8425.30	0.434
5:23:9	5:23:11	8425.30	0.434
5:23:12	5:23:18	7647.60	0.434
5:23:19	5:23:25	7203.20	0.442
5:23:26	5:23:32	7092.10	0.442
5:23:33	5:23:38	6981.00	0.438
5:23:39	5:23:43	6758.80	0.426
5:23:44	5:23:50	6758.80	0.422
5:23:51	5:23:56	6425.50	0.414
5:23:57	5:24:6	6092.20	0.410
5:24:7	5:24:14	5981.10	0.412
5:24:15	5:24:19	5870.00	0.416
5:24:22	5:24:30	5536.70	0.442
5:24:31	5:24:38	5425.60	0.438
5:24:39	5:24:45	5425.60	0.426
5:24:46	5:24:52	5314.50	0.414
5:24:53	5:24:58	5314.50	0.418
5:25:0	5:25:3	5314.50	0.418
5:25:4	5:25:9	5203.40	0.384
5:25:10	5:25:15	5092.20	0.380
5:25:16	5:25:23	4759.00	0.418
[illegible]	[illegible]:41	447[illegible].10	0.416
[illegible]	5:25:37	4314.60	0.432

6:28:43	5:28:45	648.30	0.424
5:28:49	5:28:50	537.20	0.410
5:28:51	5:28:52	537.20	0.410

ANALYSIS OF 'G' LEVELS ASSOCIATED WITH THE C-5A ACCIDENT NEAR SAIGON APRIL 4, 1975

by

James W. Turnbow, Ph.D.

Consultant - Aviation Safety

Analysis of 'G' Levels Associated
With the C-5A Accident Near Saigon
April 4, 1975

by

James W. Turnbow, Ph.D.
Consultant - Aviation Safety

References Used:

The following analyses and conclusions are based in part, but are not limited to, a review of the following documents:

1. USAF Collateral Report, Vols. I, II, III.

2. Photographs of the aircraft prior to and following the accident.

3. Photographs of the accident site.

4. Miscellaneous drawings of the C-5A aircraft.

5. Sworn statements of:

   Regina Aune
   Tilford Harp
   Christine Lieverman
   Keith Malone
   Marcia Tate

6. Depositions and/or trial testimony of the following:

   Regina Aune
   Tilford Harp (co-pilot)
   Christine Lieverman
   Harriett Neill
   Merritt Stark
   Marcia Tate
   Dennis Traynor (pilot)
   William Timm
   John Edwards

7. Wreckage Distribution Diagram.

8. Cutaway view of C-5A troop compartment.

9. NASA Technical Report SP-3006 'Bioastronautics Data Book,' 1964.

10. USAF Technical Report No. 5915 Part 2, 1961, 'Human Exposures to Linear Deceleration,' 1951.

11. USAAMRDL Technical Report 71-22, 'Crash Survival Design Guide,' 1971.

12. Plots of the Data Obtained from the onboard recorder (MADAR).

13. The author also draws on some 20 years of experience in aircraft accident reconstruction and full scale crash testing of aircraft. A vitae is attached for convenience of the reader.

ACCIDENT SYNOPSIS

- The crash of this aircraft consisted of two ground contacts separated by approximately 875 yards of free flight. The analysis of the data available shows the following concerning these two contacts:

Contact No. 1

This contact has been characterized by several of those aboard the aircraft as 'a near normal touch down' or 'no more than a hard landing typical of military or commercial aircraft.' The sink rate was reported to be 500 to 600 feet per minute by one of the cockpit crew (Mayor Traynor), a fact in agreement with:

a) Extrapolation of the MADAR data.

b) The aircraft attitude and speed, i.e., nose up at touchdown. (It is noted that the nose gear did not contact the ground at this point).

c) The aircraft would have been in 'ground effect' as it approached the surface with resulting tendency to reduce any existing sink rate.

d) Statements of other crew, for example: Capt. Harp said in the Schneider Trial, page 2143, line 4: 'I would say there were hardly any G forces on the first landing.'

The primary structural failure at this first contact was removal of the rear sets of landing gears, probably due to the landing on a less than normally firm runway and to the above normal touchdown speed of 270 knots, both of which could be expected to increase the drag forces on the gear.

Since the ultimate design load for each gear does not exceed 240,000 lbs, and assumption of full design load being developed on the rearmost gears, plus a limit load of 160,000 lbs on each of the forward main gears, gives a total load of 800,000 lbs. This would load the 450,000 lb aircraft to no more than 1.78g's along the longitudinal axis of the aircraft. The vertical loads would have been very consistent with those occuring for a landing at near or lower than normal sink rate. Vibratory oscillations would have been induced into the structure due to failure of the gear, however these, being of high frequency, would have been more of an 'audible' nature to passengers of the troop compartment rather than of a nature such as to produce a displacement or impact type response of those passengers.

No hazard to the occupants of either the cockpit or troop compartments can thus be expected from this contact.

Contact No. 2

This ground contact occurred after the aircraft became airborne following the initial touchdown and crossed the Saigon River. Observation of the forward main gear tire marks relative to a small dike on the far bank of the river shows (together with the absence of nose gear marks) that the aircraft again touched down in level or slightly nose up attitude. The extended nose gear and extended main gear permitted the aircraft to pass over this dike, allowing failure of all of these remaining gears with little or no contact of the bottom of the fuselage with the dike. The decelerations here would again be no more than the values occurring in the first contact. Upon passage over the dike the bottom of the aircraft began a skidding and plowing run through wet and soft rice fields to the final points of rest. Observation of the accident photos and other evidence shows the following:

a) The troop compartment and the crew compartments remained essentially intact, maintaining living space for those occupants.

b) All seats remained attached to the floor and there were no seat belt or harness failures.

c) Seats in the troop compartment are 16g seats attached to the floor with a 9g restraint. All were rearward facing.

d) Skid tracks through the wet/soft marsh-like terrain are strongly indicative of long-duration, low-level, constant deceleration for the cockpit and troop compartments.

e) Break-up of the lower fuselage occurred in many relatively small pieces consistent with many successive failures, again indicative of continued and hence low level continuous deceleration.

f) The failure of the side walls of the lower (cargo) compartment ultimately resulted in the formation of two skids or runners for the troop compartment which guided that compartment in almost a straight track, reducing lateral loads to only those of vibratory nature and allowing the floor to remain intact.

g) Adult occupants seated or kneeling on the floor between rows of seats, without any kind of restraint other than holding by hand were able to stay in place throughout the complete impact sequence without serious injury. Cuts and bruises were reported. Only those occupants in line with an isle and holding by hand appear to have been unable to retain position. These occupants would have been in a condition similar to a 'free fall' at a somewhat elevated 'g' value of about 1.5 to 2.0g as they 'fell' longitudinally along the isle to impact at or near the front bulkhead. Their injuries thus occurred in this mode.

The 'Wreckage Diagram' for C-5A SN 68-218 shows a deceleration distance for the troop compartment of about 650 yards or 1950 feet as scaled from the diagram. For an initial speed of 270 knots or 456 ft/sec the average deceleration over this distance is 1.66g.* In view of the nature of this accident it is the opinion of the author that the peak decelerations which occurred are probably not more than three (3) times this value or about 5g's. The reader should observe carefully the fact that such peaks cannot physically be applied for any appreciable period of time otherwise the aircraft would have to stop in much less than 1950 feet. [The value would be 646 feet at 5g's constant deceleration].

HUMAN TOLERANCE TO DECELERATION

The voluntary tolerance of the whole human body for short duration pulses with forward facing seat and shoulder harness is at least 40g's or eight times the 5g value mentioned above. For rearward facing seats the voluntary tolerance level is well in excess of 40g. At least one 80g test has been conducted on a voluntary human subject without serious injury.

The tolerance to head impact alone, as established by a Wayne State University research group, indicates that peak accelerations of 15 milliseconds duration would have to be of the order of 140g just to produce unconsciousness. For a 2ms pulse the corresponding value would have to be about 400g.

It should be noted that in the C-5A accident in question many of the children were not even awakened by the crash. In view of: 1) The visually observed response of the children in the troop compartment to the crash (or the lack thereof) and 2) to the extremely large disparity between the probable actual decelerations (both peak and average values) and the limits of voluntary human tolerance to such loads, it appears clear that no hazard to life or health existed due the deceleration environment alone in the Saigon C-5A accident of April 1975.

For the convenience of the reader, copies of several human tolerance charts taken from reference No. 10 are included in the appendix.

CONCLUSIONS

It is the opinion of this author that it is a scientific certainty that the decelerations occurring in the April 4, 1975 Saigon C-5A accident did not provide a direct hazard to the life or health of the children or adults located in troop compartment of that aircraft. More specifically it is not possible that the magnitude of the crash decelerations were such as to result in brain damage for the seated occupants or to those adult occupants who remained in position throughout the crash.

APPENDIX I

For uniform (constant) deceleration the governing equation is:

$$G = \frac{V^2}{64.4S}$$

where:

V = Velocity in ft/sec
= 270 knots = 456 ft/sec

S = Deceleration distance = 1950 feet

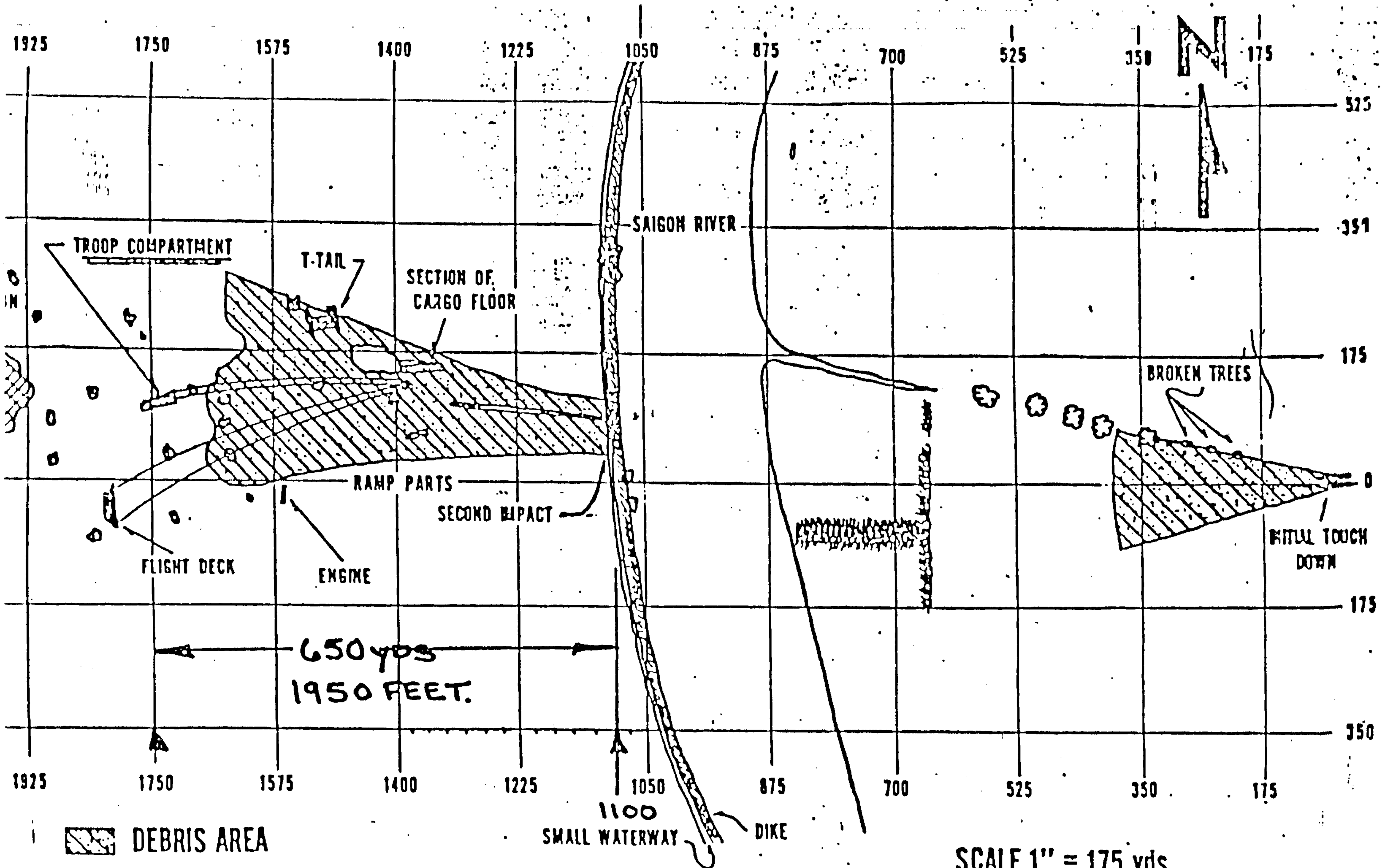
The constant 64.4 is twice the acceleration due to gravity or $2g = 2 \times 32.2 = 64.4$ ft/sec^2.

Then:

$$G = \frac{(456)^2}{64.4\ (1950)} = 1.66$$

APPENDIX II

C-5A SN 68-218 4 APRIL 1975



DEBRIS AREA

BURN AREA

SCALE 1" = 175 yds.

Distances Approximate

APPENDIX III

USAAMRDL TECHNICAL REPORT 71-22

CRASH SURVIVAL DESIGN GUIDE

REVISED OCTOBER 1971

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
FORT EUSTIS, VIRGINIA

CONTRACT DAAJ02-69-C-0030

DYNAMIC SCIENCE (THE AvSER FACILITY)
A DIVISION OF MARSHALL INDUSTRIES
PHOENIX, ARIZONA

head velocity was that value of initial velocity which resulted in the impact material's being crushed to a predetermined value of strain. This strain value was dependent on the properties of the impact material chosen. The restriction on head deceleration was defined by human tolerance limitations. The head tolerance to impact is a function of pulse duration and average head decelerations as shown in Figure 5-7. In combination, these limitations define a maximum velocity curve as a function of original material thickness, above which absence of concussion (as defined by the tolerance limit of Figure 5-7) was doubtful, regardless of impact material characteristics. This curve is presented as Figure 5-8.

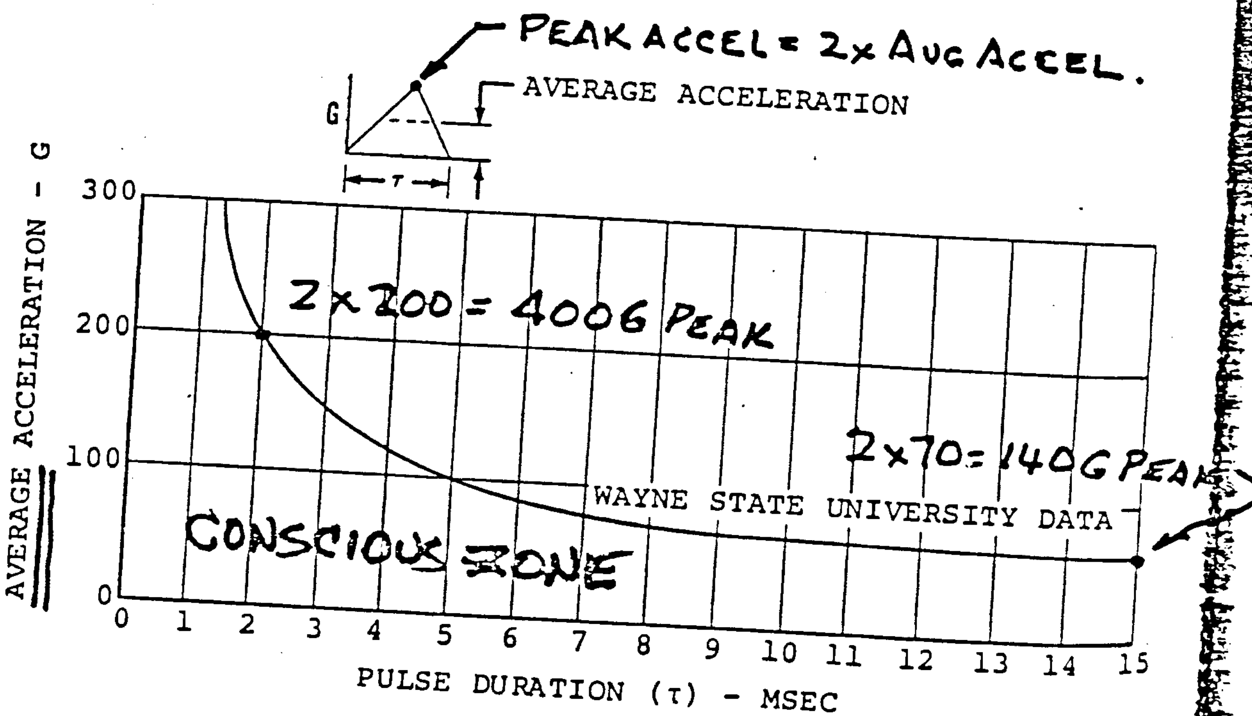


Figure 5-7. Head Tolerance to Impact as a Function of Pulse Duration as Published by Wayne State University.

5.3.3.2 Head Impact Velocities: Figure 5-9 shows typical head velocities relative to the seat as measured on anthropomorphic dummies, cadavers, and live human subjects in dynamic seat tests. Various combinations of occupant restraint were used and are so indicated on each curve.

5.3.3.3 Geometry of Probable Head Impact Surfaces in U. S. Army Aircraft: Aircraft in the U. S. Army inventory in 1965 have been examined to determine the kinds of contact hazards

APPENDIX IV

TURNBOW

NASA SP-3006

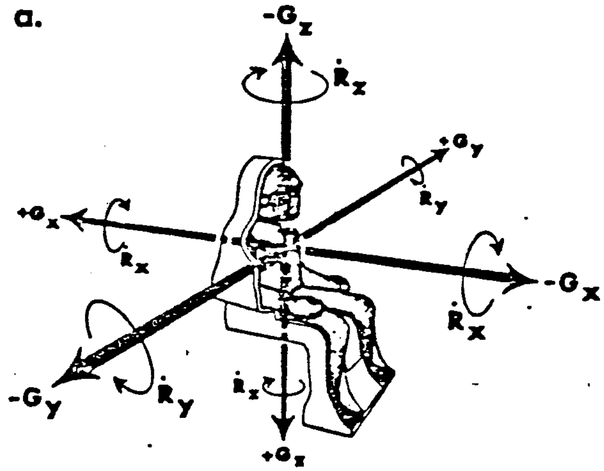
BIOASTRONAUTICS DATA BOOK

ACCELERATION – INTRODUCTION

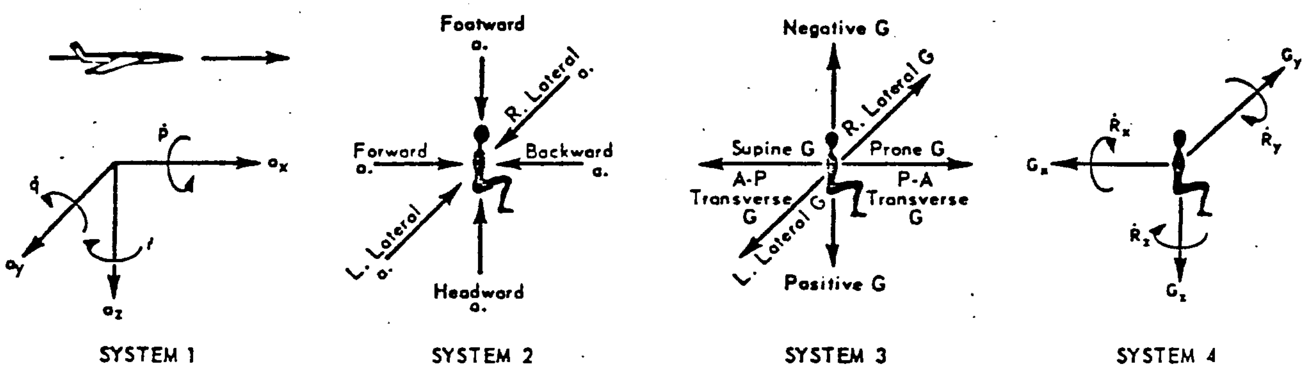
Symbols and vectors used in this book are based on the direction a body organ (e. g., the heart) would be displaced by acceleration. Table II below--and in particular System 4, which is based on displacement of body fluids--explains the most commonly employed terms.

Source: Adapted from Gell [18].

a.



b.



c.

	Table I: Direction of Acceleration		Table II: Inertial Resultant of Body Acceleration		
Linear Motion	Aircraft Vector (System 1)	Acceleration Descriptive (System 2)	Physiological Descriptive (System 3)	Physiological Displacement (System 4)	Vernacular Descriptive (System 5)
Forward	$+a_x$	Forward accel.	Transverse A-P G* Supine G Chest to back G	$+G_x$	Eyeballs in
Backward	$-a_x$	Backward accel.	Transverse P-A G Prone G Back to chest G	$-G_x$	Eyeballs out
Upward	$-a_z$	Headward accel.	Positive G	$+G_z$	Eyeballs down
Downward	$+a_z$	Footward accel. (tailward)	Negative G	$-G_z$	Eyeballs up
To right	$+a_y$	R. lateral accel. (rightward)	Left lateral G	$+G_y$	Eyeballs left
To left	$-a_y$	L. lateral accel. (leftward)	Right lateral G	$-G_y$	Eyeballs right
Angular Motion					
Roll right	$+\dot{p}$	cartwheel	Roll	$-\dot{R}_x$	
Roll left	$-\dot{p}$	cartwheel		$+\dot{R}_x$	
Pitch up	$+\dot{q}$	somersault	Pitch	$-\dot{R}_y$	
Pitch down	$-\dot{q}$	somersault		$+\dot{R}_y$	
Yaw right	$+\dot{r}$	pirouette	Yaw	$+\dot{R}_z$	
Yaw left	$-\dot{r}$	pirouette		$-\dot{R}_z$	

* A-P and P-A refer to Anterior-Posterior and Posterior-Anterior.

Source: Adapted from Gell [18]

ACCELERATION – INTRODUCTION

The spectrum of acceleration environments is extremely large and may vary in duration, magnitude, rate of onset and decline, and direction. Some acceleration exposures may be so mild that they have relatively no physiological or psychophysiological effects, or they may become so severe that they produce major disturbances. The emphasis of this section is primarily on human performance capabilities and physiological responses as they are modified by sustained acceleration. Abrupt accelerations and decelerations lasting less than two seconds are treated in Section 5, Impact and Vibration.

The unit for the physiological acceleration is G, as distinguished from the "true" displacement acceleration, generally designated by aerodynamicists with the unit g. The physiological acceleration represents the total reactive force divided by the body mass, and hence includes both displacement and resisted gravitational acceleration effects.

The physiological acceleration axes represent directions of the reactive displacements of organs and tissues with respect to the skeleton. Please refer to the accompanying diagrams and tables. The Z axis is down the spine, with $+G_z$ (unit vector) designations for accelerations causing the heart, etc., to displace downward (caudally). The X axis is front to back, with $+G_x$ designations for accelerations causing the heart to be displaced back toward the spine (dorsally). The Y axis is right to left, with $+G_y$ designations for accelerations causing the heart to be displaced to the left.

Angular accelerations which cause the heart to rotate (roll) to the left within the skeleton are specified by the $\dot{R}_x$ unit vector, representing radians/sec^2 about the X axis. Angular velocities in the same sense are specified by the $+R_x$ unit vector, representing radians/sec about the X axis. Similarly, $+\dot{R}_y$ represents an angular acceleration producing a pitch down of the heart within the skeleton, and $+\dot{R}_z$ represents yaw right of the heart within the skeleton.

The field of acceleration research has produced a number of general principles concerning the effects of acceleration stress on physiology and performance. The following statements, many of which are illustrated in the charts of this section as shown, are hoped to be useful to designers of aerospace vehicles and equipment.

1. Physiological tolerance, or the ability to withstand acceleration physiologically, is a function of many variables--e.g., rate of onset (3-2); direction of G vector (3-3); magnitude of G (3-2); duration (3-4)--as well as the type of endpoints that are used as criteria.

2. In addition to the physiological tolerance limits which define the end points for reliable functioning of any particular physiological system during exposure to acceleration stress, there are also performance tolerance limits, which define the end points for reliable functioning of any particular performance ability.

3. Physiological and performance tolerances may be functionally related, but they need not be the same, since each is dependent upon the criteria used.

4. During exposure to acceleration stress, the type of G-protection system used has a very important influence on the pilot's ability to tolerate acceleration (chart 3-5), perform tasks, and maintain performance proficiency.

5. For an acceleration of given rate of onset and magnitude, physiological tolerance is highest for $+G_x$, next for $-G_x$, next for $+G_z$, and lowest for $-G_z$, directions of force. See 3-3.

6. Acceleration stress significantly impairs visual capabilities. As acceleration increases, visual acuity decreases (see 17-30), illumination requirements increase, and brightness contrast requirements decrease (3-10 and 3-11).

7. Major individual differences exist among pilots in their ability to perform piloting tasks during exposure to high G.

8. Certain types of acceleration exposures produce illusions, or false perceptions, of one's position and motion. These may occur in some pilots during or after the acceleration exposure.

9. Since acceleration training results in physiological adaptation and conditioning to G, as well as learning to make performance compensations, acceleration training produces major improvements in performance proficiency during exposure to high G.

10. The instrument display characteristics of a piloting task influence the measurement of performance capabilities of a pilot during exposure to high G. Among the more important display characteristics are: the position of the display instrument within the pilot's visual field, the degree of interpretation required of the pilot, the number of instruments that must be viewed by the pilot during high G, the amount of illumination, the amount of brightness contrast, the physical form in which the display information is presented, and the amount of visual instrument scanning that is required at high G.

11. The characteristics of the control device used by the pilot in performing under G have a significant effect upon proficiency. These characteristics are: the number of axes of motion; the location of the axes of motion with respect to the G and the pilot's hand; stick force gradients along each mode of control; the centering characteristics along each mode of control; dead band zone; breakout force requirements; control friction; static and dynamic balance; damping characteristics; control throw; response time of control; control harmony; cross coupling characteristics; size and shape of grip; dynamic and static balance; and control sensitivity (3-16).

12. Acceleration impairs the ability of the pilot to sense changes in control characteristics that may occur as a function of specific acceleration vectors. This may be a direct effect of the acceleration forces on the receptors, effects on the central or autonomic nervous system, or an effect on circulatory and other physiological systems which indirectly affect the ability of the pilot to sense changes in his arm, hand, and fingers.

13. Task characteristics that are relatively easy to perform in low-G environments become more difficult as G increases.

14. Intellectual skills, piloting concentration, time perception, judgment, and immediate memory are influenced by high G.

15. Response time, as well as complex psychomotor performance, is influenced by high G (3-13).

16. Anticipation of acceleration may produce emotional reactions that are greater in terms of psychophysiological impairment than the direct effects of acceleration itself.

17. If, in addition to acceleration stress, the pilot is exposed to other environmental stresses, his responses may be altered by the combined effects of these stresses. (See Section 9).

Positive (G_z) and transverse (G_x) accelerations have been emphasized in studies to date, while lateral and angular accelerations have received relatively little attention, primarily because of the lack of proper research facilities.

Some limitations in interpreting acceleration research data are: (a) most studies have been conducted on a small number of subjects; (b) repeated exposure to acceleration changes a subject's G tolerance, and this factor is usually not included; (c) emotional condition and motivation influence results; (d) instrumentation has not been standardized for measuring the effects of G on physiology and performance.

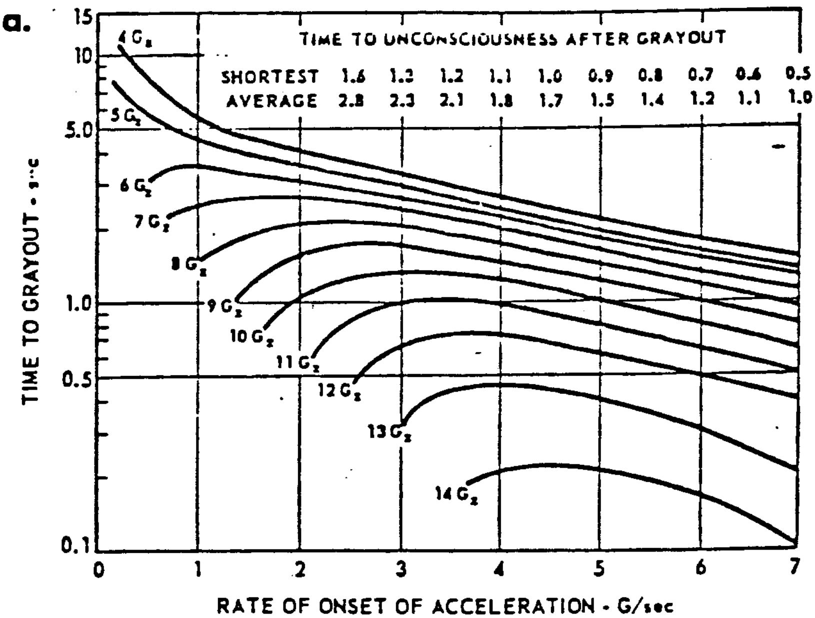
Recommended for general reading are the following: Otto H. Gauer and George D. Zuidema, Gravitational Stress in Aerospace Medicine [17]; Neal M. Burns, Randall M. Chambers, and Edwin Hendler, Unusual Environments and Human Behavior: Physiological and psychological problems of man in space [5]; and C. C. Clark, J. D. Hardy, and R. J. Crosbie, A Proposed Physiological Acceleration Terminology with an Historical Review [12].

GRAYOUT AND RATE OF ONSET OF $+G_z$

This graph relates the onset rate of acceleration to time-to-end-point. It shows that for any given positive acceleration (G_z) from 4 to 14 G, the time to grayout depends on how rapidly the acceleration level was reached. Further, the table inset in the graph shows the shortest times and the average times for unconsciousness to develop following grayout, each pair of values being related to an onset rate. For example, at onset rate of 4 G/sec, the shortest time to unconsciousness was 1.1 sec, and the average 1.8 sec.

Source: Stoll [26].

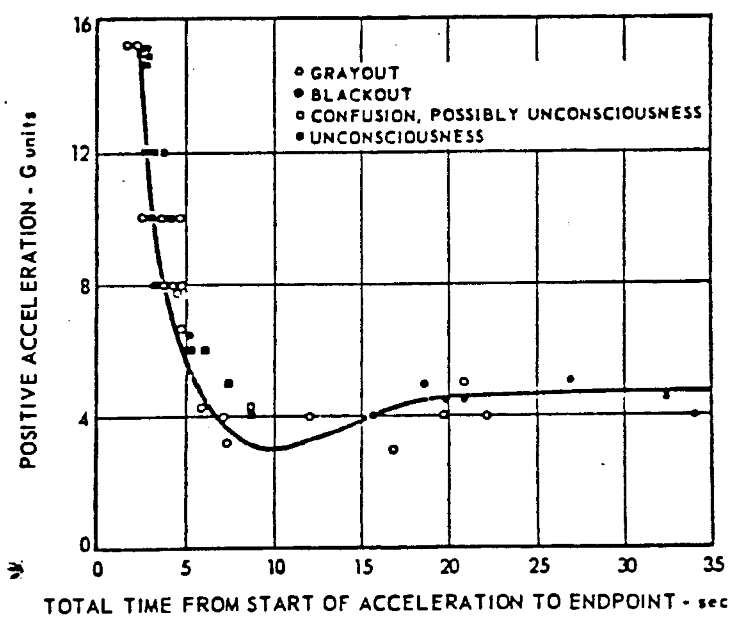
a.



This graph shows human tolerance to positive G_z for varying rates of onset, G amplitudes, and exposure times.

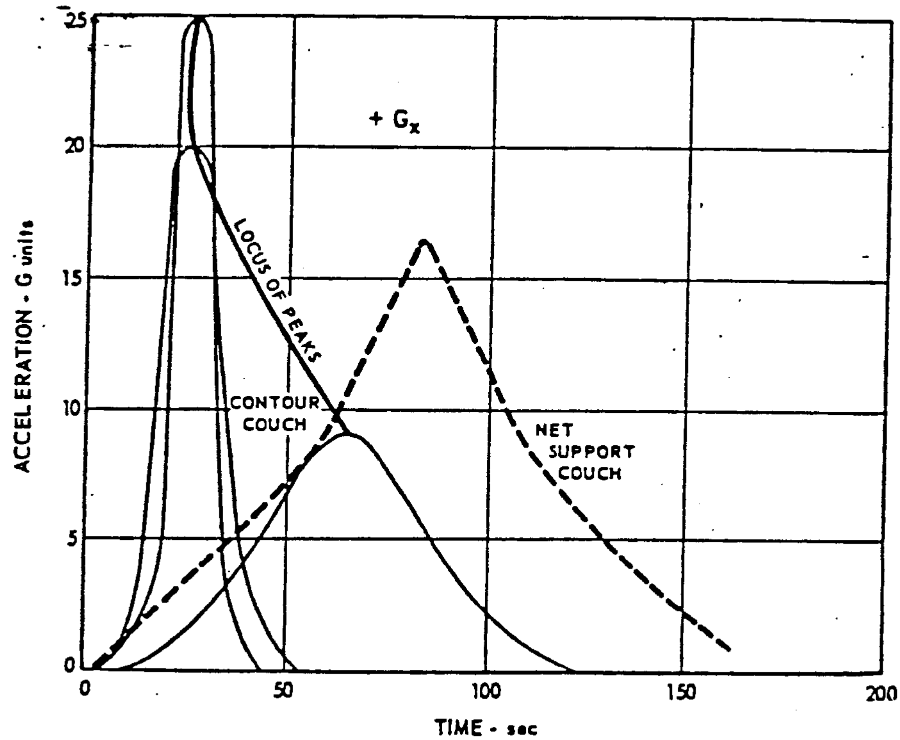
Source: Adapted from Stoll [26].

b.



MAXIMUM TOLERABLE ACCELERATION PROFILES

a.



b.

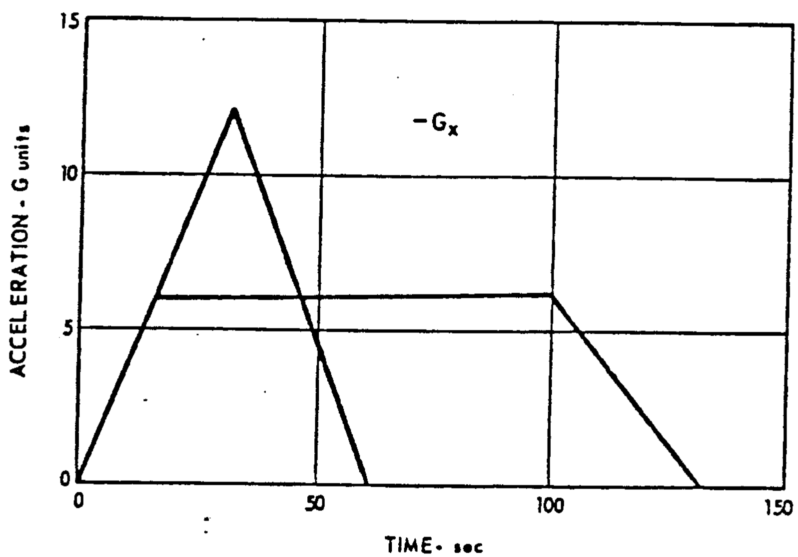
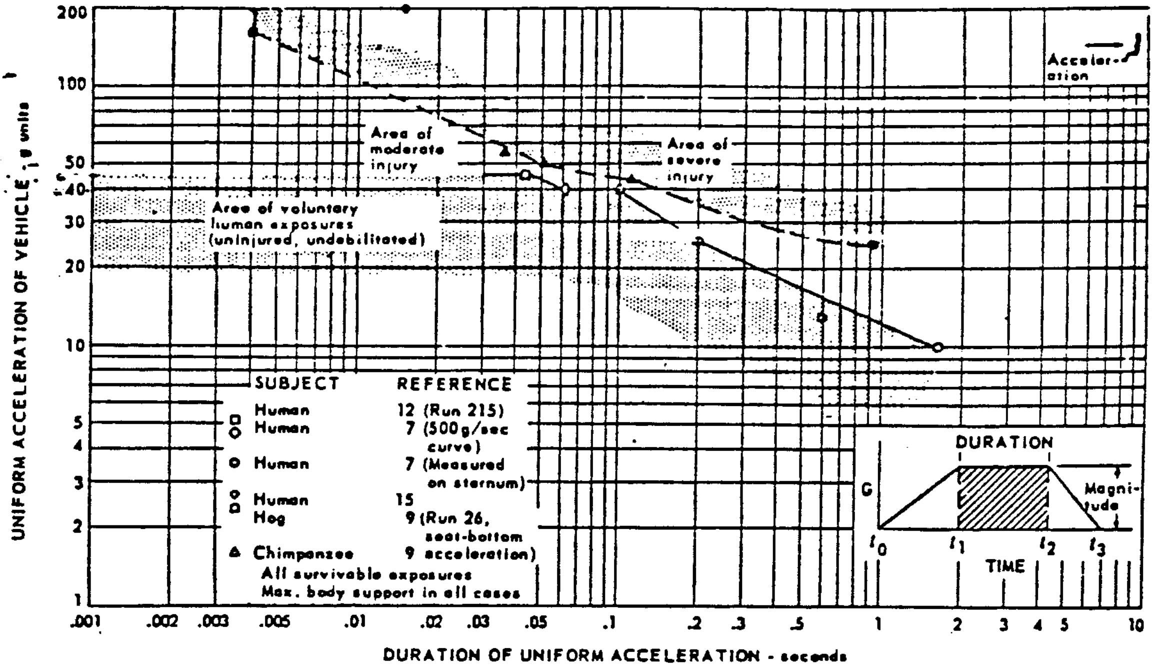


Figure a shows the greatest acceleration-time histories that have been tolerated on centrifuges when special support structures and positioning are used. Solid lines show three curves which define about the same area of $+G_x$ times time. A heavy line connects the peaks of these three curves and locates the peaks of other curves enclosing the same area. The dashed line encloses a number of possible acceleration profiles related to space flight, all of which are tolerable, since the border of the envelope has been tolerated experimentally. Figure b depicts two tolerable $-G_x$ accelerations (eyeballs out) when the subject is restrained in a special harness.

Sources: Bondurant et al. [4]; Clarke et al. [13]; Lawton et al. [24]; Collins et al. [14];

a.

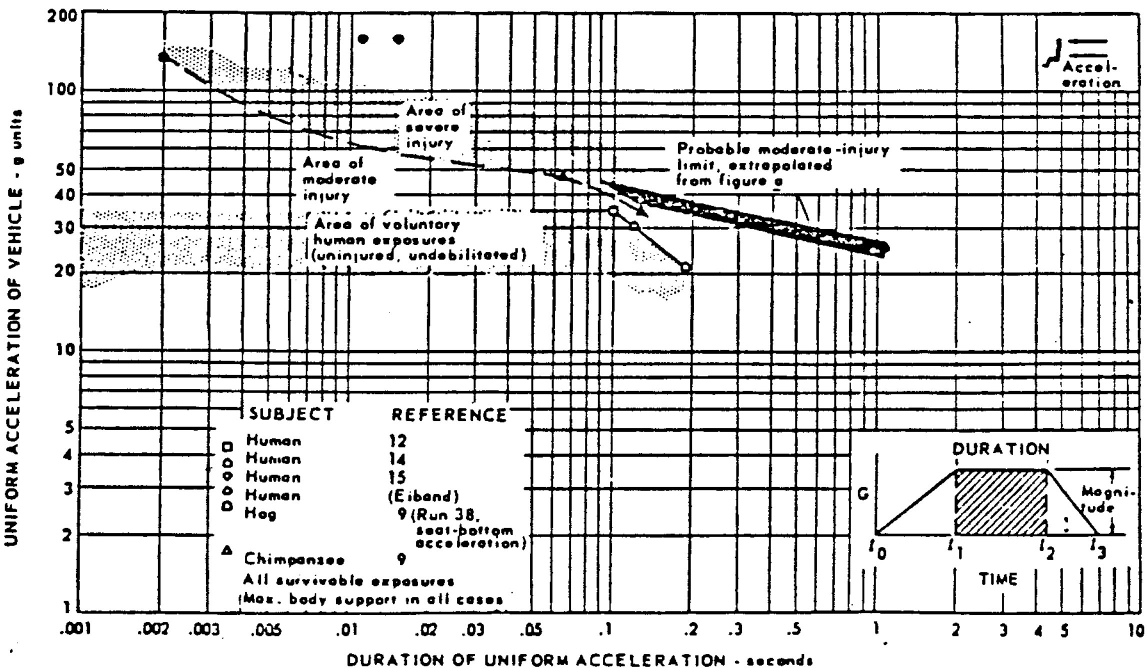


These two graphs show the durations and magnitudes of abrupt transverse decelerations which have been endured by various animals and man, showing areas of: voluntary endurance without injury; moderate injury; and severe injury. Graph a summarizes $-G_X$ data (back to chest acceleration) and b shows $+G_X$ data (chest to back acceleration). Reference numbers on the graphs are those in the original reports.

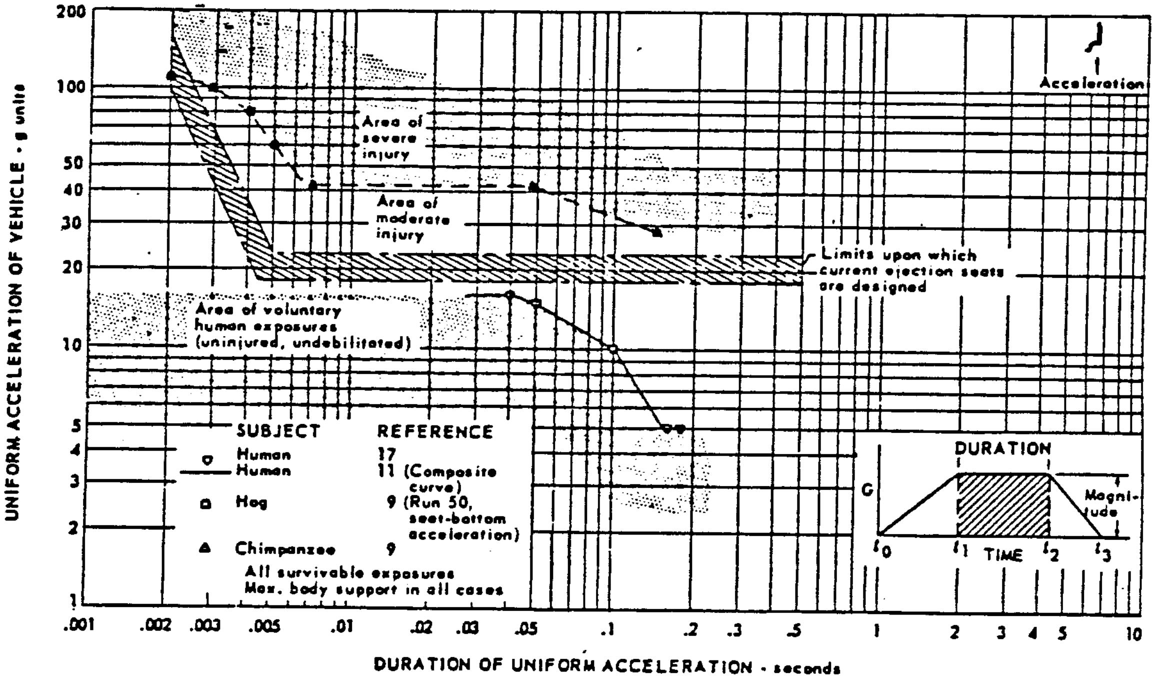
Source: Eiband [5].

REARWARD FACING

b.



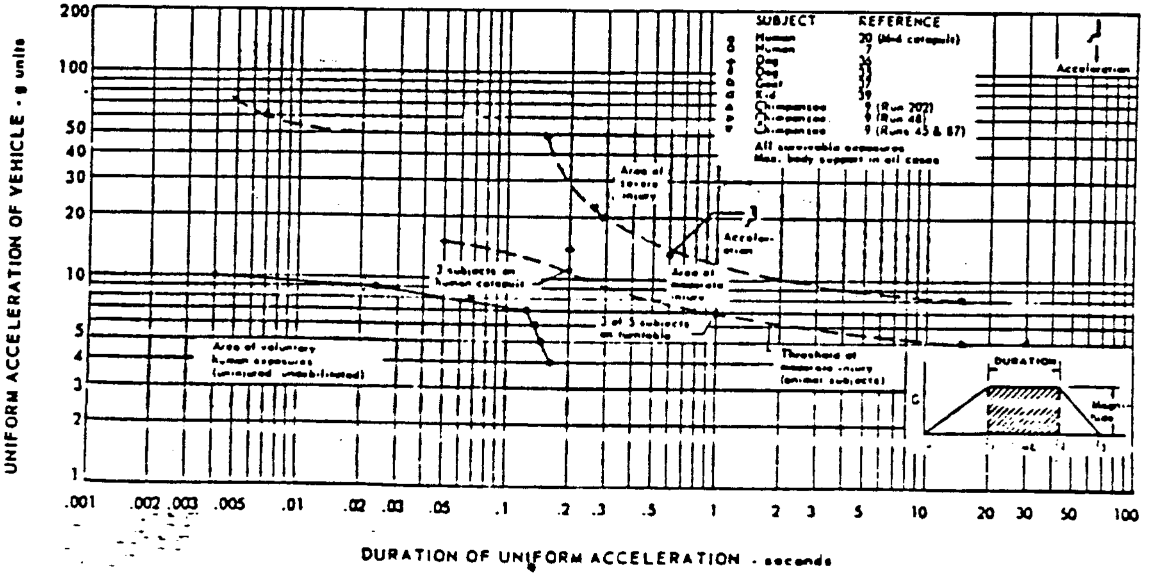
a.



These two graphs show the durations and magnitudes of abrupt deceleration in the G_z (longitudinal) directions which have been endured by various animals and man, showing areas of voluntary endurance without injury, moderate injury, and severe injury marked by shading. Graph a shows data of $+G_z$ acceleration (headward), and b shows data fcr $-G_z$ acceleration (tailward). Reference numbers on the graphs are those in the original reports.

Source: Eiband [5].

b.



ARIZONA STATE UNIVERSITY

James W. Turnbow
Professor of Engineering

Degrees:

Ph. D.	University of Texas, 1959
M.S.E.M.	University of Texas, 1952
B.S.M.E.	Texas Technological College, 1940

Academic Experience:

1971-	Director Crash Injury Investigators School, Arizona State University
1959-	Arizona State University, Professor
1948-59	University of Texas, Assistant Professor
1948	Texas Technological College, Student Instructor
1940-41	Oklahoma A. & M. College, Instructor

Industrial Experience:

5/44-9/47	North American Aviation, Design Engineer
7/41-4/44	U. S. Army, Captain, Ordance Department

Consulting Experience:

1972-	Aviation and Automotive Accident Investigation for various legal firms
1/72	Consultant to Sikorsky Aircraft, Stratford, Connecticut
9/60-6/69	Consultant to the Flight Safety Foundation, AvSER Div., Phoenix, Arizona
9/54-9/59	Balcones Research Center, University of Texas, Research Engineering

Awards, Scholarships, and Honor Societies:

Tau Beta Pi
Alpha Chi
Convair Excellence in Teaching Award, U. of Texas
Honor ME Graduate, Texas Tech
Honor Military Graduate, Texas Tech
Sigma Xi Member

Membership in Scientific and Professional Societies:

Registered Professional Engineer, Texas and Arizona

Principal Areas of Research and Teaching Interest:

Dynamics, Vibration, Impact, Space Mechanics, Aviation and Automotive Safety

Principal Publications:

"Cushioning for Air Drop, Part I," (with other authors). Published for the Quartermaster Food and Container Institute for the Armed Forces, Chicago, Illinois, July 1955, 80 pp.

"Cushioning for Air Drop, Part II, Air Drop Cost Analysis," (with C. C. Steyer). Quartermaster Food and Container Inst. for the Armed Forces, Chicago, Ill., April 1956, 37 pp. Unscheduled presentations of portions of this work were presented by Dr. Turnbow at two meetings: (a) Aerial Delivery Research Contractors Coordination Meeting at the Midwest Research Inst.,Kansas City, Mo., Jan., 1956, and (b) The Aerial Delivery Research Symposium at Fort Lee, Virginia, April 1956.

"Cushioning for Air Drop, Part III, Characteristics of Paper Honeycomb under Dynamic Loading," Quartermaster Research and Engineering Command, Natick, Massachusetts, August 1956, 9 pp.

"Cushioning for Air Drop, Part VII, Characteristics of Foamed Plastics under Dynamic Loading," Quartermaster Research and Engineering Command, Natick, Massachusetts, March 1957, 14 pp.

"High-Velocity Impact Cushioning, Part I, Drop-Test Facilities and Instrumentation," Quartermaster Research and Engineering Command, Natick, Massachusetts, August 26, 1957, 31 pp.

"High-Velocity Impact Cushioning, Part II, Energy-Absorbing Materials and Systems," Quartermaster Research and Engineering Command, Natick, Massachusetts, August 26, 1957, 41 pp.

"Properties of Materials at High Strain Rates, Part III, Material Properties and Wave Propagation," The Sandia Corporation, Albuquerque, New Mexico, January 5, 1959, 174 pp.

"High-Velocity Impact Cushioning, Part IV, The Effect of Moisture Content and Impact Velocity on Energy-Absorption Characteristics of Paper Honeycomb," Quartermaster Research and Engineering Command, Natick, Massachusetts, May 1, 1959, 40 pp.

"High-Velocity Impact Cushioning, Part V, Energy-Absorption Characteristics of Paper Honeycomb," Quartermaster Research and Engineering Command, Natick, Massachusetts, May 25, 1959, 106 pp.

"Application of Cushioning to Complex Structures," Aerial Delivery Impact Conference, Balcones Research Center, The U. of Texas, June 1959.

"The Energy-Dissipating Characteristics of Airbags," Quartermaster Research and Engr. Command, Natick, Mass., August 16, 1959, 52 pp.

90 yds – assumed length of furrow on E side.

$F_{max} = 250{,}000$

$s = 270$ ft

$Wk = \frac{1}{2} bh = \frac{1}{2} S F_{Max}$

$= \frac{1}{2}\ 270 \times 250000$

$= \underline{33.75 \times 10^6 \text{ ft lbs}} / \text{gear}$

$KE_{init} = \frac{1}{2} m V_i^2$

$= \frac{1}{2} \frac{451{,}000}{32.2} (455)^2$

$= \underline{1.4498 \times 10^9 \text{ ft lb}}$

$\Delta KE = Wk$

$KE_{final} = KE_{init} - Wk$

$= 1.45 \times 10^9 - 33.75 \times 10^6$

$= \underline{1.41607 \times 10^9 \text{ ft lb}}$

$V_f = \sqrt{\frac{2\ KE_f}{m}}$

$= \sqrt{\frac{2 \times 1.42 \times 10^9}{\frac{451{,}000}{32.2}}}$

$= \underline{449.67 \text{ ft/sec}}$

$\Delta v = V_i - V_f = \underline{5.327 \text{ ft/sec}}$

$\Delta t_{i-f} = \frac{s}{V_{avg}} = \frac{270}{\frac{455 + 450}{2}} = \underline{0.597 \text{ sec}}$

$a_{avg} = \frac{\Delta V}{\Delta t} = \frac{5.327}{0.597}$ ~~$\frac{452.34}{0.597}$ = 757.8 ft/sec² 23.53 g's~~ 8.92 ft/sec^2 $\underline{0.277 \text{ g's}}$

$$V_f = V_i - a_{avg}\,\Delta t$$

$$= 455 - 8.92 \times 0.597$$

$$= 450 \text{ ft/sec}$$

---

on an impulse-momentum basis

$$\int F\,dt = \Delta mv$$

$$\frac{1}{2}\,150{,}000 \times 0.597 = \frac{451000}{32.2}\left(455 - V_f\right)$$

$$V_f = 455 - 5.328$$

$$= \underline{449.672 \text{ ft/sec}}$$

DATA ON OCCUPANTS OF TROOP COMPARTMENT

ITEM NO.	NAME	SEATING INFORMATION BEFORE LOCATION*	ATTITUDE	AFTER LOCATION*	ATTITUDE	BRIEF INJURY SUMMARY	REMARKS
1	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—

etc.

* ASSIGN LOCATION NOS. TO OCCUPANTS IN SPECIFIC LOCATIONS -- ASSIGN LOCATION LETTERS TO AREAS TO DEFINE GENERAL AREA WHERE SUBJECT RESIDED WHEN SPECIFIC POSITIONS ARE UNKNOWN.

3/8/80

Med. Workshop - Hyatt - Rosslyn -

Attendance incl'd experts, treating physicians, attorneys & representatives of Lockheed

Dr. Brooke (phonetic) - attending pediatrician - conditions (acc. environ

1. Hypoxia 2. decompression 3. toxic gases (CO), 4. cyanide poisoning (CN_2)
& 5. deceleration

Hazards associated with decel -

1. external - force application & distribution from external obj.
2. internal direct - organ damage from inertial loads & tea
3. internal latent - neurological, physiological & psychological damage that may not show up immediately

Dr. Brooke - pediatrician

Dr. Redmond - also a pediatrician

Dr. Den Hof -

Dr. Berman - neuro-psychologist

Dr. Snyder - human tolerance

Cohen, Jrz, Snyder, Mason, David Abrahamson, Geo Bugby
medical investigation of children that survived
C5A accident - Colateral report initially unavailable until '77
FFAC (Friends for All Children) sponsoring ag. for bringing
children back from Viet Nam - in Apr. 75 - a church sponsored group.
Rosemarie Taylor - '67 - opened nursery - start adoption procedures - from facilities in Siagon - very high quality operation - provided specialized care of all types (incl. well). - - purpose of FFAC was to make the child adoptable - - for adoption in Europe, Australia or U.S.
Apr 4, 75 - 228 children from Siagon in C5A - - at +15 min lock syst. on rear door failed & door blew out at 23-24K feet - - destroyed controls - no O_2 for children - - Crash landed 20 min later in rice paddy at 270 knots - -
Fatal to 78 children - ~~&~~ 30 adults - - for the children the report says 98 - - which is wrong. Children survivors were evac'd after 20 min & completd by 2 hr. - - taken to Siagon hosp & examined by phys. & released to FFAC - - They then were sent overseas to SF on 747 & arrived 4/6 & were disbursed to families following day.
FFAC brought suit against Lockheed based on potential injuries sustained based on reptd defects in A/C - in Dec last yr. Lockheed admitted liability & agreed to pay ~~admitted~~ proven damages.
Judge Oberdorfer in DC apptd Guardian Ad Litem

medical evaluation - 38 US & 56 France &
Lux, Fin, Swed, etc.

Initially not concerned w/ acc. environment... mostly concerned w/ children. The investigation employed scientific methods to follow the children incl. control group. Invest. of FFAC which showed it to be a good org. - Started in Dec 78 -- w/ 5 boys & 5 girls - Exam revealed children had sustained number of injuries, however they were minimal. - Selection was "random" but stay in Wash D.C. area. Major focus was on org. brain inj.

Began looking for correlative data on refugee children in order to compare performances of children on plane w/ those not on plane -- substantial differences were found in the cognitive functioning of the 2 groups - Dr. Den Hof (phonetic) reviewed the records & noted pattern of abnormal perf. of all children immed. after the crash. This occurred in Saigon & again in S.F. ~~The concern~~

THE CONCERN HERE SEEMS TO BE RELATED TO THE EXP. DECOMPR. & HYPOXIC ~~EFFECT ON~~ CONSEQUENCES ON LATTER COGNITIVE FUNCTIONING OF THE CHILDREN. THERE MAY BE SOME CONSIDERATION OF TOXIC EFFECT OF THE PROD. OF COMBUSTION. CUMULATIVE & COMBINED EFFECT OF ALL THESE FACTORS.

Funding is from settlement from Lockheed to G&L.

* - Concerned from an engr. standpoint of how the g-loads may be superposed on the degrading cog. funct. of children. - Lockheed was asked if they performed kinematic analysis.

* Cohen is interested in defining a kinetic environment for a typical seat. Subsequently he wishes to define the dynamic loading on the ...

1. Inspect the damaged parts / floor for the survivable areas of A/C
2. Inspect an undamaged C5-A
3. Construct a seating pattern for children
4. " " F.R.P. " " "
5. Define failure patterns
6. Analyze failures → theoretical vs test results -- to define loads levels that are associated w/ failures
7. Correlate loads on occupants with findings in it 6 -- use the med'l. descriptions of injuries

---

What Cohen wants to know is "what is the level of accel on the floor" of the upper passenger level.

This work is defined by Cohen as being research oriented, but the 1st trial occurs next week. This will be followed by a 2nd & perhaps a 3rd & then probably a settlement will be reached. It has been reported by consultants that there are 78 children that were injured & 100% so far have sustained reduced cognitive function and that it would take about $500K per child to care for them throughout their lifes

Prepare a proposal of what needs to be done to collect data from the people ~~from~~ at Kelly AFB.

Meeting at Hyatt at 1000 A -

~~Flight deck~~

Lt. Seat - Capt Traynor

Rt. Seat - Capt. Harp

Jump Seat - Capt Malone

Engr at the Panel — Sgt. Engels - first engineer

Capt Melton

Loadmaster - Sgt. Snedegar

Aft Latrine w/ 7 yr. old child on lap mate ~~Troop Compartment~~ - T Sgt. Doughty - attend in galley area

Head set ~~" Crossladder~~ SMSgt Perkins - behind Aune ~~holding onto frame~~

Navigator - Capt Langford

Upstairs Troop Compartment - T Sgt. Parker - behind Aune ~~assisting Sgt. Perkins~~

Upstairs Fwd Floor bulkhead ~~Latrine~~ - One child about 13 yrs of age

Fwd bulkhead - flight nurse

~~Engr. at the Panel - T Sgt E~~

Upstairs - Babies & ½ med crew - 2 per seat

aisle, midway troop compartment. upstairs ~~in galley~~ ~~downstairs along the lits~~ - Lt. Aune - head - med crew - sitting on floor

upstairs - Lt. Wirtz - med crew - behind Aune a few rows inside aro.

upstairs - Sgt. Gnerek

downstairs - Sgt Wise

upstairs - Sgt Hadley - in front of Aune a few rows in aisl.

downstairs - Col. Willis - ~~sitting beside Aune~~

downstairs - Capt Klinker -

downstairs - Lady w/ cast on - across from Aune - laid on blan.

downstairs - Sgt Paget

upstairs - Lt. Goffinet - up front near latrine -

Upstairs - Sgt Boutwell

Major Wallace - flight crew

1. Seating configuration for this A/c
2. Location of as many occupants as possible at the time of the crash.
3. Photos of any interior damage of troop compartment and flight deck
4. Location of any seating or floor components for my inspection
5. CSA inspection by JRC - same seat config. (permission to take photos)

CROMACK ENGINEERING ASSOCIATES, INC.

Mailing Address: P. O. BOX 28243
TEMPE, ARIZONA 85282
Area Code 602/831-7512

MEMORANDUM

TO William Timm

DATE 6/23/80

FROM Robert Cromack

SUBJECT C5A Case

Enclosed are the photographs which I took during our inspection of the C5A on June 19, 1980.

TRAVEL ITINERARY

TO: ML & MMH

FROM: DLT

RE: TRAVEL ARRANGEMENTS FOR J. ROBERT CROMACK
TICKETS TO BE PRE-PAID ON 3/3/80

DEPART:

3/6/80 Phoenix, Arizona via American #366 (COACH)
1:15 P.M. Arrive St. Louis 4:56 P.M. (LUNCHEON FLIGHT)

DEPART:

3/6/80 St. Louis, Missouri via American #680 (COACH)
5:35 P.M. Arrive Washington National 8:35 P.M.
This is a Dinner Flight

DEPART:

3/8/80 Washington National via American #267 (COACH)
7:20 P.M. Arrive Chicago 8:30 P.M.

DEPART:

3/8/80 Chicago Airport via American #157 (FIRST CLASS)
9:20 P.M. Arrive Phoenix, Arizona 11:45 P.M.

HOTEL:

Marriott Key Bridge -Rosslyn
Single Room; One Night 3/6/80
Guaranteed Late Arrival - Michelle

1401 Lee Highway
Arlington, Virginia
(703) 524-6400

Hyatt Rosslyn
Single Room; One Night 3/7/80
Guaranteed Late Arrival - Nancy

1325 Wilson Boulevard
Arlington, Virginia
(703) 841-9595

DEFT. EX. DD- Cromack Exh 16
DATE: 10-27-81
REPORTER: ALBERT J. GASDOR

PROJ 1089

2/20/80

Mar 6 — LV PHX AA366 at 1315 hr
AR ST LOU

LV ST LOU AA 680
AR WASH NATL at 8:25 P

MAR 8 — LV DCA AA 267 at 1920 hr.
AR CHI

LV CHI AA 157
AR PHX at 2345 hr

FILE RESTRAIN (CREATION DATE = 08/08/79)

* * * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
TYPERSTR
BY TESTTYPE
* PAGE 4 OF 6

TYPERSTR	COUNT / ROW PCT / COL PCT / TOT PCT	CAR-FRNT FLAT BR 1	CAR-FRNT ANGL BR 3	CAR-FRNT TO POLE 4	CAR-ROLL OVER 6	OTHER 1 CAR CFIG 7	2 CAR-FU LL FRNTL 8	2 CAR D-O OVRLAP 9	2 CAR P-P OVRLAP 10	2 CAR-FF 0 9TO12 11	2 CAR-FF 0 12TO3 12	ROW TOTAL
AB RS WITH BELT	10	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	112
		0	0	0	0	0	0	0	0	0	0	4.5
		0	0	0	0	0	0	0	0	0	0	
INFLATABLE BELT	11	2	0	0	0	0	5	1	1	3	1	
		1.3	0	0	0	0	3.3	.7	.7	2.0	.7	152
		.9	0	0	0	0	6.8	2.4	7.1	18.8	6.3	6.1
		.1	0	0	0	0	.2	.0	.0	.1	.0	
CHLD RES W BELT	12	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	111
		0	0	0	0	0	0	0	0	0	0	4.4
		0	0	0	0	0	0	0	0	0	0	
OTHER	16	3	0	0	0	0	0	0	0	0	0	
		3.3	0	0	0	0	0	0	0	0	0	92
		1.4	0	0	0	0	0	0	0	0	0	3.7
		.1	0	0	0	0	0	0	0	0	0	
	17	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	3
		0	0	0	0	0	0	0	0	0	0	.1
		0	0	0	0	0	0	0	0	0	0	
COLUMN TOTAL		215	16	11	17	4	74	42	14	16	16	2501
		8.6	.6	.4	.7	.2	3.0	1.7	.6	.6	.6	100.0

(CONTINUED)