2253 November 19, 1975

MEMORANDUM

TO: 2112/George Hurrell

FROM: 2253/John Szuch

SUBJECT: Coordination of FSER Flutter and Controls Programs on XD11 Engine

This memo is intended to provide information requested at the 11-18-75 meeting with Pratt & Whitney, AFAPL and Lewis personnel associated with the XD11 tests planned in PSL-1. I also want to keep you abreast of the status of the Multivariable Control Synthesis Program regarding interface hardware definition, instrumentation requirements and control test conditions.

At the 11-18-75 meeting we were requested to provide a list of conditions we would like to run in PSL-1 on XD11. At this time we can only assume that all of the points being used by Systems Control to design the controller are to be checked in PSL. These points are plotted in figure 1 and are listed in Pratt's 5th Status Report on contract F33615-75-C2048. As the design process continues and as evaluation criteria are established by P&W, NASA, and AFAPL, these points can be better defined. We would appreciate your comments regarding the PSL-1 capability to run these points. We would also appreciate your forwarding this list of points to Barry Romoser at FRDC so that he can review the points and comment on the XD11 tolerance to running at these conditions. We need this information (both facility and engine limits) as soon as possible so we may scope the experimental and analytical controls work.

As I indicated in the meeting, we've estimated a total run time of 66 hours based on a factor of 3 to cover unexpected software and/or hardware problems. Approximately 55 percent of the time will be spent on transient testing. At this time we can only estimate an equal distribution of time between low and military power operation (only limited afterburning is planned). It is expected that some of the data (both steady-state and transient) that we will want on the bill-of-material control can be obtained during the preceding core flutter tests. We should coordinate our plans on test conditions, etc. as soon as possible.

Our definition of the control interface hardware requirements will be based on a comparison of P&W suggested interfaces and other options such as separate fuel pump and 4-way valving of main fuel flow, etc. Unfortunately, there has been a delay in Pratt providing their recommendations. At this point, AFAPL is trying to expedite the process. It is expected that the nozzle and CIVV control will be controlled in the same manner as was done in the FX213 fan flutter tests. The only difference would be the computer-input command to the servos. Boonshaft fail-safes would be used. RCVV control would be similar, but Pratt has expressed concern about a fixed fail-safe position. They are to provide us with recommendations as to how a variable fail-safe could be implemented. Our current thinking about main fuel flow control involves 3-way valving of flow from either the UFC or research control metering valve to the engine. Pratt's recommendation will probably show an identical UFC metering valve module being servo-driven with 3-way valving of UFC and research control metering valve ΔP's for the control of the main fuel variable displacement pump. The UFC would be used for AB control, startup and fail-safe main fuel control. We certainly should have Pratt's interface recommendations by December 1, and will be able to define our hardware requirements at that time.

I am enclosing a list of instrumentation that SCI has deemed to be desirable from a control standpoint. Pratt is to send me a list of instrumentation that will be available on XD11. I would appreciate your inputs as to the availability of instrumentation to supplement the existing XD11 instrumentation.

John R Szuch

John Szuch

2 enclosures

cc/
2200/M.A. Beheim
2250/D.I. Drain
2253/J.R. Zeller
2110/R.G. Willoh
2153/F.J. Kutina
2153/W.A. Bishop
2253/J.R. Szuch w/o attach.

2253:JRSzuch:if:11-19-75

2253

January 7, 1976

Mr. W. Earl Hall, Jr.
Systems Control, Inc. (Vt)
1801 Page Mill Rd.
Palo Alto, CA 94304

Dear Mr. Hall:

I have discussed your selected operating points and preliminary instrumentation requirements (Oct. 27, 1975 memorandum from R. J. Adams to Ron Miller) with our operations personnel. These discussions were aimed at (1) identifying operating points that cannot be run in our PSL-1 altitude facility, and (2) identifying engine parameters that cannot be easily measured.

In general, altitudes lower than 10,000 ft cannot be run in PSL-1 due to the difficulties in maintaining the engine face conditions over the duration of the tests. This would affect your points 1, 6, 18 and 19. Also, points 10 and 17 are beyond the capabilities of PSL-1, since the airflow requirement (engine plus cell cooling) is beyond the capabilities of the exhaust system. The highest altitude that can be simulated for Mn = 2.5 is about 55,000 ft. Because of these facility limits, it will be necessary to find alternate test conditions that will yield the desired control performance information. We would appreciate your suggestions regarding alternate test points.

It appears that all priority 1 instrumentation will be provided except for TT5. There will, however, be a TT6M measurement. The lower priority instrumentation will be provided except for PT5, PT7M, and TT7M. Measurements of PT6M and PS6.8 will be available. Again, your comments regarding these limitations would be appreciated.

My phone conversation with Rich Adams on December 17, 1975 indicated that your current set-point schedules make use of both fan and compressor exit Δ P/P signals. Attachment 5 in Ron Miller's November 14, 1975 memorandum to Les Small shows the following measurements on engine XD11:

PT2.5C	- 3	each at	68°,	248°,	338°	locations	
PT2.5H	- 3	" "	23°,	113°,	293°	"	
PS2.5C	- 1	" "	90°,	270°,	315°	"	(inner wall)
	- 1	" "	"	"	"	"	(outer wall)
PS2.5H	- 1	" "	45°,	90°,	270°	"	(inner wall)
	- 1	" "	"	"	"	"	(outer wall)
PT3	- 2	" "	67°,	157°,	292°	"	
PS3	- 1	" "	50°,	143°,	323°	"	(inner wall)
	- 1	" "	"	"	"	"	(outer wall)

The actual signals used to compute the Δ P/P parameters would probably consist of averages of some of the above measurements. As soon as possible, we would like your views on answers to the following questions:

1. Which signals should be utilized?

2. How should they be averaged?

3. How accurate do the individual measurements have to be?

4. What are the high-frequency response requirements for these and other measurements (pressures, temperatures, speeds)?

Rich Adams also suggested that communication begin between Ron Dehoff and Dave Cwynar concerning the SEL 810B implementation of the control logic. Feel free to call us concerning any questions you have about the hybrid or experimental phases of the program.

Sincerely,

John R. Szuch

John R. Szuch
Aerospace Engineer

cc:

2200/M.A. Beheim
2250/D.I. Drain
2253/J.R. Zeller
2253/J.R. Szuch

Ron Dehoff - SCI
Richard Adams - CTI
Charles Skira - AFAPL
Ron Miller - P&WA FRDC

2253:JRSzuch:if:12-29-75

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO 44135

REPLY TO
ATTN OF: 2153

December 2, 1975

MEMORANDUM

TO: 2253/John Szuch

FROM: 2153/Thomas Kirchgessner

SUBJECT: F-100 Controls Program

REF: Memo to George Hurrell from John Szuch, dated November 19, 1975

We have evaluated the capabilities of PSL to perform the operating points of consideration for the F-100 controls program. The specific points we have evaluated are those listed on the attached table, which is part of the memo originating from S.C.I., dated October 27, 1975.

Sea level conditions cannot be met in the facility, and hence points 1, 6, 18 and 19 would have to be altered slightly. The greatest compromise would be for point 6, where approximately three or four thousand feet would be the lowest simulated altitude attainable.

It also appears that points 10 and 17 are beyond the capabilities of PSL. The total required air flow (engine plus cell cooling) would be too great for our exhaust system to handle. Matching the Reynolds Number Index of test points 10 and 17, the highest altitude condition we can simulate is about 55 to 60 thousand feet. Would test conditions in this range be adequate to complete your test envelope?

In the referenced memo there is a statement concerning the expectation that some of the steady state and transient data can be obtained during the core flutter test. We would like to discuss this point with you. There may be problems and hazards involved in obtaining data (especially transient) during the core flutter program.

We have checked the instrumentation requirements list against what will be supplied as part of the XD-11 FSER program. It appears that all priority 1 instrumentation will be provided except for T_{T5} (Fan Turbine Exit Temperature). The lower priority instrumentations will all be provided except for:

P_{T5} (Low Turbine Exit Total Pressure)
P_{T7M} (Augmentor Pressure)
T_{T7M} (Augmentor Exit Temperature)

At the present time we have no information on the instrumentation - control computer interface requirements. We will need to know the required input signal ranges.

Thomas A. Kirchgessner
Thomas A. Kirchgessner
Attachment

cc:
2153/T. Kirchgessner
2112/G. Hurrell
2112/C. Mehalic
2150/File
2100/AED File

2153:TAKirchgessner:bmr:12-2-75

Priority Number	Mach Number	Altitude	PLA	Criteria
Group 1				
1	0	0	24°	To verify the adequacy of the choked and unchoked model representation.
2	.9	10,000	83°	
3	.3	20,000	24°	
4	.6	10,000	20°	
5	.6	30,000	24°	
Group 2				
6	1.2	0	83°	To establish the range of operating extremes the LQR will encounter.
7	2.2	40,000	83°	
8	.9	45,000	130°	
9	.9	65,000	83°	
10	2.5	65,000	130°	
Group 3				
11	1.2	10,000	83°	To investigate the effects of stability extremes and engine limits on the linear models and the control design
12	1.2	20,000	83°	
13	1.8	20,000	83°	
14	.9	30,000	83°	
15	.3	20,000	83°	
Group 4				
16	1.8	40,000	83°	Compressor stability
17	2.5	65,000	83°	Compressor stability
18	0	0	83°	Turbine deterioration
19	0	0	83°	Overall deterioration
20	.9	45,000	40°	Burner pressure lower limit

RJA/lb
10/27/75

2253

December 19, 1975

MEMORANDUM

TO: 2210/Facilities and Engineering Branch

FROM: 2253/Head, Digital Control Systems Section

SUBJECT: Request for Operations Engineering Support for F-100 Multivariable Controls Program

The Digital Control Systems Section is presently engaged in a joint program with the AFAPL to evaluate the usefulness of using modern optimal control design techniques to design controls for advanced air-breathing propulsion systems. The program involves the efforts of two contractors as well as that of a number of people in my section. A modern control design for the F-100 hybrid engine will first be evaluated on a real time hybrid engine simulation here at LeRC. Then the control laws will be evaluated on an actual Series II-3 (XD11)F-100 engine in the PSL (Cell #1) facility.

The scope of the PSL evaluation, the requirements for special control sensors and the hardware needed to interface with the digital computer controller in the 8x6 is presently being coordinated by John Szuch of my section. He has been working with the contractors and the Research Operations personnel in the Airbreathing Engines Division to begin definition of the needed equipment.

John, however, also has the responsibility for monitoring the contractors' activities as well as insuring that all LeRC analytical tasks are completed and ready for the hybrid evaluation. Therefore, some assistance in the area of experimental research facility setup would be very helpful to this program. We need an experienced operations engineer to serve as an interface between ourselves and the PSL operations personnel in specifying and selecting various pieces of interface hardware and special sensors needed to accomplish the PSL test program. PSL operations will still be responsible for the test setup, but we need to carefully specify to them the type of hardware needed for controls work.

Such an individual should be familiar with the requirements of mating a computer control with electrohydraulic research servos. Frank Paulovich has this type of experience and has provided this assistance in the past. If you provide Frank or someone else who may be more available, I estimate the task will require about 15% of the individual's time over the next four months. After that there will be a minimal effort required while the F-100 undergoes some core flutter tests. Then there would be a 15-20% activity in the fall to assist in checking out the research hardware prior to the controls test.

If there are any questions concerning this request, please contact me or Dan Drain.

John R. Zeller

cc:
2200/M.A. Beheim
2250/D.I. Drain
2251/L.M. Wenzel
2253/J.R. Szuch

2253:JRZeller:if:12-19-75

J. Szuch

March 24, 1976

Frank Kutina,

Per our discussion of 3/23/76, we arrived at some estimates of funding and manpower needed from your division for the F-100 controls tests in PSL #1. It was estimated that with the 250-270 points that we plan on acquiring, there would be some 10-12 weeks of PSL testing. This is based upon 2 nights/week with about six (6) hours of testing per week. There will be 3-4 weeks of set-up and installation time required for a total program of almost 4 months. You estimated that during this period there would be 5 Operations Prof. and 3 Research Prof. with a total of 16 support personnel.

The funding of IMS monies needed is listed below.

PSL Charges	12K
Fuel	20K
Hardware	6K
Instrumentation	10K
Servo Eq. & Switching Valves	5K
360 Computer Time	7K
Tape Recorder	25K
TOTAL	85K

The above information will be factored into the Task being written for this program. Also, I am aware that these estimates are only for the Series II engine. Considerable additional costs will occur if we decide to go to a -026 engine for the controls program.

Jack Zeller

Szuch 166

2253 December 30, 1975

MEMORANDUM

TO: 2110/Chief, Engine Research Branch

FROM: 2253/John Szuch

SUBJECT: Mach Number Simulator for F15 Flight Engine Calibration

In response to our December 10 meeting on the above subject, I conducted a study using our F100 (3) steady-state digital deck. This study was aimed at gaining some insight into the role played by the measured flight Mach number in the Electronic Engine Control (EEC). It was hoped that the study would help answer the question, "Is a Mach number simulator needed for engine calibration in PSL?". The deck was used to generate operating line data at the nine flight conditions you specified. They are: 10,000 ft/0.1 Mn, 6800 ft/0.6 Mn, 14180 ft/0.9 Mn, 45,000 ft/0.9 Mn, 40,000 ft/1.2 Mn, 50,000 ft/1.2 Mn, 40,000 ft/1.4 Mn, 45,000 ft/1.8 MN, 50,000 ft/1.8 Mn, and 45,000 ft/2.2 Mn. At each flight condition, the deck was run in two ways. First, it was run normally with the flight Mach number input to the EEC. In PSL, this would require the Mach number simulator. The second mode of running the deck corresponded to no Mach number input to the EEC. For this case, the EEC assumes a value of 0.8.

A Mach number input to the EEC is used to perform three basic functions. First, it establishes a minimum value for the rate-limited power lever angle (PLAPMN) (see fig. 1). For example, power lever angles below intermediate are not permitted when Mach number exceeds 1.4. Secondly, Mach number is used to establish limits on fan corrected airflow to ensure satisfactory inlet performance. These limits are set by EEC schedules G_{14} and G_{22} (see fig. 2). Finally, the Mach number is used to establish a different nozzle expansion ratio above $M_n = 1.05$ (see fig. 3).

The attached data are the results obtained from the deck. The primed quantities correspond to the no Mach number input case. The results can be summarized as follows:

1. The four lowest Mach number points can be run with no Mach number input to the EEC without affecting the engine operation from idle to maximum power.

2. The M_n = 1.2 points can be run with no Mach number input to the EEC without affecting the engine cycle balance from PLA = 57 degrees to maximum power. Absence of the Mach number input also allows operation down to PLA = 26 degrees. The engine thrust is increased by two percent due to the reduced expansion ratio, however (see fig. 4).

3. The M_n = 1.4 point can be run with no Mach number input to the EEC without affecting the engine cycle balance from intermediate to maximum power. Absence of the Mach number input also allows operation down to PLA = 22 degrees. The engine thrust is increased by 2.7 percent due to the reduced expansion ratio.

4. If the Mach number simulator were to be used for the M_n = 1.8 points, the fan corrected airflow would be limited to 196.7 pps at intermediate (see fig. 2). With no Mach number input to the EEC, the airflow will be 202 pps at intermediate and operation down to PLA = 20 degrees will be possible. The engine thrust is increased by 6.8 pe percent due to the reduced expansion ratio.

5. If the Mach number simulator were to be used for the M_n = 2.2 point, the fan corrected airflow would be limited to 160.6 pps at intermediate. With no Mach number input to the EEC, the airflow will be 176.7 pps at intermediate and operation down to PLA = 20 degrees will be possible. The engine thrust is increased by 12.3 percent due to the reduced expansion ratio.

It should be noted that the G_{14} schedule is ineffective at these operating conditions, since uptrim of the area is prohibited below intermediate, and the airflow at intermediate exceeds the G_{14} scheduled value in each case (see fig. 2.

It appears that the Mach number simulator is not needed for the F15 flight engine calibration, since it would only be effective at the two highest M_n points at power lever angles above about 76 degrees. It may also be desirable to run below intermediate power at the higher Mach numbers. If thrust measurements are considered to be important, the need to run with the proper expansion ratio might dictate the use of the Mach number simulator, however.

John R. Szuch

Attachments (5)

cc:
2200/M.A. Beheim
2250/D.I. Drain
2253/J.R. Zeller
2112/H.G. Hurrell
2112/C.M. Mehalic
2153/F.J. Kutina
2153/W. Bishop
2253/J.R. Szuch

2253:JRSzuch:if:12-30-75