Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Royal Netherlands Air Force
Koninklijke Luchtmacht

NLR-TP-2001-327

RNLAF/NLR flight test for certification of Lockheed Martin Overseas Corporation Enhanced Targeting Pod and BAe Systems Falcon Owl Navigation Pod

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Summary

The Royal Netherlands Air Force has carried out an analysis and test program with the F-16A/B (Mid Life Update version) aircraft for the airworthiness certification of the Lockheed Martin Overseas Corporation “Enhanced Targeting Pod” and the British Aerospace Systems “Falcon Owl” navigation pod (earlier known as “Atlantic” Navigation pod).

Structural loads, Flight handling, and mainly the subjects Flutter and Limit Cycle Oscillations and finally Store separations are addressed in this document.

Analysis of structural loading of the aircraft in the external stores configurations and under the operational conditions showed no overload cases.
Ventral fins were instrumented to investigate loads and vibrations due to the addition of inlet mounted pods. Comparison of configurations with the navigation pod or targeting pod, with configurations without the pods, showed increases in vibration levels; the most on the targeting pod side. As a consequence the chance of fatigue damage to the ventral fins will increase.

Flight handling was analyzed and flight tests were executed. The results of this analysis were that the impact of the pod(s) on the departure sensitivity was minimal within the defined operational envelope of the aircraft. Significant deterioration was only found well outside the envelope.
To verify the analysis, test flights in “worst case” external store configurations, without and with pods, were dedicated to verifying the flight handling characteristics. The results confirmed the analysis; in general they were judged “satisfactory”. Configurations with substantial asymmetric loads showed unacceptable flying qualities when rolling maneuvers were initiated at negative normal load factor (inverted flight). However, such operations are excluded in the aircraft’s flight manual.

Simulations and earlier flight test results were used to analyse flutter and Limit Cycle Oscillation behavior. In this analysis no significant influence of the pods on the flutter / Limit Cycle Oscillation behavior was found. Further flight tests in a number of worst case configurations confirmed the analysis results. Some configurations, however, were considered not acceptable, both with and without pods, and were not certified; other configurations were certified with restricted flight envelopes.

Analysis of earlier separations of 370 gallon wing pylon tanks (Royal Netherlands Air Force and United States Air Force) showed that addition of the navigation pod would have minimal effect on the tank separations. Three test flights have been executed in order to establish possible influence of inlet mounted pods on the separation behavior of wing pylon tanks. The tanks were released at identical flight conditions from the left wing in three different configurations of which two with the Falcon Owl pod. All three tanks made contact with the left ventral fin on the aft fuselage of the F-16 test aircraft.
The tests and analyses showed that:

- The Falcon Owl navigation pod does not significantly change the trajectories of the released 370 gallon pylon tanks.
- Adding the Falcon Owl pod does not affect the tank jettison limits.
- The 370 gallon tank released from the left wing of a certified configuration without the Falcon Owl navigation pod struck the ventral fin in conditions under which a previous, USAF certification flight test program showed a clean tank separation from the right wing.

- Because of the left tank - ventral fin interference problem new tank jettison limits are issued by USAF/SPO/F-16. The new limits are adopted for the RNLAF F-16A/B with the Enhanced Targeting Pod and the Falcon Owl Navigation Pod.

The investigation into the left tank - ventral fin interference problem is a separate task, not related to the Falcon Owl pod, and of a general concern to the F-16 user community. An initial comparison of left hand and right pylon tank releases indicates that there is difference in tank separation trajectories for LH and RH tanks.

Contents

(66 pages in total)

Abbreviations, acronyms and symbols

AF01, AF02, AF07, AF08	Tip launcher accelerations
AFSTY, AFSTZ	Pilot seat accelerations
AIM-9	Missile
AIM-120	Missile
ALQ	ALQ-131 store
AOA	Angle-of-Attack
AYP, AZP	Lateral and vertical aircraft accelerations
CAS	Calibrated Air Speed
DTHR	Throttle position
ECM	Electronic Counter Measures
FL	Flight Level
FSX, FSY	Stick forces
FTI	Flight Test Instrumentation
GBU	Guided Bomb Unit
KCAS	Knots Calibrated Air Speed
LAU-129	Missile launcher for AIM-120 and AIM-9
LCO	Limit Cycle Oscillation
LH	Left Hand
LMAC	Lockheed Martin Aeronautics Company
LMOC	Lockheed Martin Overseas Corporation
M (MA)	Mach number
MK-84	Heavy store
MLU	Mid Life Update
NAV pod	Falcon Owl (earlier called Atlantic) Navigation Pod
NLR	National Aerospace Laboratory NLR – The Netherlands
PIDS	Pylon Integrated Dispenser System
PIDS-3	Weapon Pylon with PIDS
PT	Pylon tank
PSD	Power Spectral Density
RH	Right Hand
RP	Pitch rate
RNLAF	Royal Netherlands Air Force
RR	Roll rate
RY	Yaw rate
SPO F-16	System Program Office F-16
sta	pylon station (examples: sta 1/9 are LH/RH wing tips, sta 5 is under fuselage)
TGT pod	Enhanced Targeting Pod
USAF	United States Air Force
WPS	Standard Weapon Pylon
16S210	Missile launcher for AIM-9
46TW/SK	46th Test Wing / Seek Eagle

Symbols

X	x	position change of store
Y	y	position change of store
Z	z	position change of store
PSI	ψ	psi, yaw angle change of store
TET	θ	theta, pitch angle change of store
PHI	φ	phi, roll angle change of store

1 Introduction

The Royal Netherlands Air Force adds new equipment or stores to their operational aircraft at a regular basis. To support analysis, evaluation and testing of the resulting new combinations of aircraft and equipment or loads and stores, the RNLAF utilizes an instrumented F-16B aircraft. Analysis and test support is provided usually by the National Aerospace Laboratory NLR.

This paper presents details of an F-16 flight test program with a navigation pod and a targeting pod, which are new to the RNLAF.

First a short description is given of the F-16B test aircraft used in the test program.
Then the scope of the test program is described.
A general overview is given of the subjects:
- Structural strength and Fatigue
- Flight handling analyses and flight tests.

The two main subjects of this publication are:
- Flutter and Limit Cycle Oscillations (in Chapter 5)
- Tank Separations (in Chapter 6).

2 Description of RNLAF flight test aircraft and NLR data processing facilities

The F-16A was introduced in the Royal Netherlands Air Force (RNLAF) in 1979. Within a few years the RNLAF and the National Aerospace Laboratory NLR (NLR) started flight testing of new systems (Orpheus reconnaissance pod, VER-4 bomb rack, etc.) on the F-16, using dedicated, limited instrumentation for the projects. In 1984 NLR installed a data acquisition system in an F-16A test aircraft (Ref. 1), which was transferred to an F-16B a few years later. This has been in service until May 2000 for a multitude of projects. With the introduction of the F-16MLU NLR was tasked to provide a new data acquisition system for that aircraft. The MLU test aircraft became operational in June 1999 (see Fig.1). In Ref. 2 the system is described extensively. Below follows a short description.

Fig. 2 and Fig. 3 depict the added instrumentation components and their locations in the aircraft. The test instrumentation is well equipped for stores qualifications programs. The following (groups of) parameters are recorded:

- aircraft position, attitude and derivatives
- air data (including angle of attack / side slip boom)
- aircraft configuration (landing gear position, door positions, fuel state)
- pilot inputs, control surface responses
- local structural strain and vibration (wings, center section, ventral fins)
- separation parameters (camera control and signals, release events).

Parameter sample rates can be (pre-)programmed individually, typically between 1 Hz for configuration parameters to 2500 Hz for strain- and vibration measurements.
All data is recorded from engine start before take-off to engine shut down after landing. A measurement run is marked with a unique recording number. The recording medium is a Hi-8 VCR tape.

For store separation tests high-speed film cameras can be installed in a (left-hand or right-hand) wing tip or under wing mounted, modified (missile) launcher and in fuselage mounted camera boxes.

A personal computer based facility at the aircraft home base (Leeuwarden Air Force Base) enables a post-flight check on data consistency and a quick look analysis of the test results. For further analysis the tape is transferred to the flight test data analysis facility of NLR in Amsterdam. This facility converts the bit stream on the VCR tape to time histories of parameters in engineering units.

Separation films are developed within one day and post processed at NLR.

3 Scope of the tests

In 1997 the RNLAF ordered a number of BAe Systems “Falcon Owl” forward looking infra red navigation pods (in short: NAV pod) and a number of the Lockheed Martin “Enhanced Targeting Pods” (in short: TGT pod) for the F-16MLU aircraft. NLR was tasked to assist the RNLAF with the airworthiness qualification of the pods for the F-16MLU aircraft.

The “Falcon Owl” is new to the F-16 and is a derivative of the Atlantic NAV pod, as used on other aircraft types. The differences between the two asked for a thorough analysis and testing of the pod itself. The new pod is smaller than the LANTIRN “Pathfinder” NAV pod, which is in use on the F-16C/D. Both pods are carried in the same position, on the left side of the air intake of the F-16. The expectation was that the combination F-16A/B + Falcon Owl would require no extensive flight test program to clear a safe flight envelope.

The Enhanced Targeting Pod is a derivative of the LANTIRN Sharpshooter targeting pod as in use on the F-16C/D. The external shapes are identical and, while the internal systems have changed, the masses are nearly the same as well. This was reason that the actual certification activities, concerning the TGT pod, could be limited to paperwork. Actually much confidence was built by a “quick action qualification” of the original LANTIRN targeting pod for the RNLAF F-16A (OCU), based on the F-16C/D configurations, including a series of flight tests in the Netherlands, in preparation of taking part in NATO operations.

Apart from operational requirement of the new systems, the flight safety subjects to be considered, analyzed and tested, are:

- Aircraft system integrity after integration of the new systems with the aircraft (Electro-Magnetic Compatibility and Electro-Magnetic Interference or EMC and EMI)
- Structural strength and fatigue
- Flying qualities
- Flutter, vibration and limit cycle oscillations (LCO)
- Store separation.

After finishing the necessary paperwork as described in Ref. 3, and pre-flight analysis, flight tests were conducted.

The subjects LCO and store separation are presented separately in Chapters 5 and 6. The test results for the other subjects are compiled in the next Chapter.

4 General results

4.1 Structural strength and fatigue

Discussions with aircraft manufacturer Lockheed Martin Aeronautics Company, revealed possible overloading of the aircraft center section structure and the tail control surfaces due to inlet mounted stores. Lockheed Martin was subcontracted to analyse the structural loading of the aircraft in the external stores configurations and under the operational conditions as defined at the start of the program. This analysis showed no overload cases.

F-16 ventral fins can be damaged or may even separate from the aircraft as a result of oscillatory loads on the fins due to e.g. upstream mounted bodies. In the F-16 MLU program improved fins have been adopted. Six flights with the test aircraft in external store configurations with and without pods have been dedicated to the ventral fin issue. During each ventral fin flight, slow accelerations from M = 0.6 to maximum allowable speed, followed by a sudden deceleration (throttle chop) were carried out at various flight levels. The slow accelerations and throttle chops were chosen because, from earlier experience, it was known that these maneuvers might excite the ventral fins. The ventral fins were instrumented with two vibration transducers and three strain gauges each. Also the skin panels, to which the fins are attached, were equipped with two strain gauges each. The analog signals from the 14 transducers were “low-pass filtered” at 640Hz and subsequently sampled at 2500 Hz. The filter and sample frequencies have been based on results on the ventral fin ground vibration tests.

After the flights the data was converted to engineering units, and power spectral density plots were made of the parameters in comparable speed ranges.

Comparison of a configuration with the NAV pod with a configuration without the NAV pod but otherwise similar, showed no significant difference in excitation levels. The slender shape of the NAV pod apparently has a minor influence on the structural dynamical behavior of the ventral fins.

Comparison of a configuration with the TGT pod with a configuration without the TGT pod, but otherwise similar, showed an increase in excitation on all right hand ventral fin and skin panel transducers by about a factor of two to five in effective value, but only during the slow accelerations. As a consequence the chance of fatigue damage to the ventral fins shall increase. The bluff body shape of the TGT pod may cause the higher vibration levels.

4.2 Flight handling analyses and flight tests

The external store configurations (including downloads, which are sub-configurations that appear, after one or more stores of the take-off configurations have been released) were simulated with NLR's Active Control Technology computer program. The program is based on block diagrams from manufacturer's publications and completed with manufacturer provided aerodynamic data. The simulations were performed along the following lines:

1. Pilot inputs for a number of standard maneuvers, well known for their potential departure hazard to the F-16 (maximum deflection aileron rolls initiated at increasing angle of attack, at negative load factor and from opposite turn , maximum deflection rudder roll, windup turn, straight pull-up, to name a few, were defined. For each maneuver departure criteria were defined.
2. For each configuration the aircraft response to standard inputs was simulated. Using the departure criteria, each configuration was given a departure sensitivity rating.
3. The configurations were sorted with the rating, this list was compared with experience and test results of more or less similar configurations. The list was re-arranged if judged necessary.
4. The most critical configurations were chosen for flight test.

The results of this analysis were:

- No re-arrangement of the list was necessary.
- The impact of the pod(s) on the departure sensitivity was minimal within the defined operational envelope of the aircraft. Significant deterioration was only found well outside the envelope.

In order to verify the analysis results seven test flights in "worst case" external store configurations, without and with pods were (partly) dedicated to verifying the flight handling characteristics. The results confirmed the analysis and were, in general, judged "satisfactory". Configurations with substantial asymmetric loads showed unacceptable flying qualities when rolling maneuvers were initiated at negative normal load factor (inverted flight). However, such operations are excluded in the aircraft's flight manual.

5 Flutter and Limit Cycle Oscillation analysis and flight testing

The F-16 is well known for its Limit Cycle Oscillation instability behavior, which is (non-linear) flutter with non-diverging amplitude. The flutter analysis capability available at NLR has been used to predict possible occurrence of flutter/ LCO as a function of the NAV pod and TGT pod configurations.

5.1 General

At the start of the program some concern was raised about a possible negative influence of chin-mounted pods on the flutter/ Limit Cycle Oscillation (LCO) behavior of the aircraft. Therefore it was decided to investigate this behavior as a function of the stores configuration. Preflight analyses have been performed as reported in Ref. 4. The methods and tools used in the analyses are documented in Ref. 5.

As a part of the certification effort, nineteen test flights have been executed in the period from July 1999 to October 1999 with mass models of the pods on the RNLAF F-16MLU test aircraft J-066. Five flights have been dedicated to the flutter/ LCO issue; data of eight other flights has also been taken into account.

Two flights were chosen to assess the influence of the pods on the LCO behavior, one in a LCO prone external store configuration but without NAV pod and TGT pod, and a second in nearly identical configuration with pods.
The results of the analysis showed an unexpected, but significant influence of the pods, be it with limited data, and some concern about the repeatability between the two tests. As a result, no firm conclusion about the reason could be drawn. It was decided to repeat the flights, which happened on 26 June 2000.

In section 5.2 the experimental set up is described, in section 5.3 the results of the data analysis are given. In section 5.4 some conclusions will be drawn.

5.2 Experimental set up

5.2.1 External store configurations

The flutter/ LCO flights were flown in external store configurations as per Table 1. See Ref. 6 for more details of the stores.

A standard set of maneuvers (identical to the “Volkel” flight test program, see Ref. 7 has been executed during each flight. Table 2 lists the maneuvers, together with the flight numbers and recording numbers. Flight 10a and 10b have been executed on 26 June 2000, the preceding flights in the period from July 1999 to October 1999.

5.2.2 Instrumentation

In addition to the standard Flight Test Instrumentation (FTI) system, both tip launchers were instrumented with 2 accelerometers (Fig. 4). The accelerometers were mounted inside the tip launchers with their sensitive axes in the vertical direction.
The accelerometer signals were filtered with 6th order band pass Butterworth filters with a low cut off frequency of 0.16 Hz and a high cut off frequency of 48 Hz. The filtered signals were sampled at a rate of 312.5 per second and recorded on the FTI system for post flight analysis, together with general aircraft parameters. Table 3 lists the parameters used in this analysis.

5.2.3 Data processing

After a flight the selected parameter recordings have been processed at the data post processing station at NLR Amsterdam. This station is under configuration control and delivers data to the performance level as agreed upon by the customer. The station converts in flight recorded (bit stream) data into time histories in engineering units.

5.2.3.1 Accelerometer 2-second PSD values

The tip launcher accelerations (AF01, AF02, AF07, and AF08, see Table 3) time histories have been converted to spectral values on a PC running *'MATLAB version 5.3.0.10183 (R11) on PCWIN'*.
Processing of tip launcher signals for cases of level, accelerated speed-runs, was by chopping the signals in small time segments.
Power Spectral Densities (PSD) have been calculated in two-second time segments using Welch's method, with 625 point Fast Fourier Transforms and using a 625 point Hanning window. The Mach number and Calibrated airspeed data within the two-second time segments were averaged to arrive at representative values for PSD results for each two-second segment
A MATLAB procedure was developed to process the measured and converted data (see Ref. 8).

5.2.3.2 Time history plots

The following time history plots were produced for further analysis:
- tip launcher accelerations (AF01, AF02, AF07, AF08),
- pilot seat accelerations (AFSTY, AFSTZ),
- stick forces (FSX, FSY)
- Mach number (MA), calibrated airspeed (CAS) and throttle position (DTHR)
- pitch-, roll- and yaw rate (RP, RR, RY),
- lateral and vertical aircraft accelerations (AYP, AZP)

For tip launcher signals, recorded during stabilized test runs (fixed conditions), one ten second time segment was selected to calculate Power Spectral Densities, also using Welch's method, resulting in a 3125 point Fast Fourier Transform and a 3125 point Hanning window. The PSD's have been plotted from 1 to 40 Hz. The small variations in the intended constant Mach and Calibrated airspeed signals were averaged.
Processing was performed using MATLAB procedures (see Ref. 8).

5.3 Analysis results

The primary purpose of the analysis is the assessment of any influence on the flutter/ LCO behavior of the aircraft due to the presence of the NAV pod and/ or TGT pod. The secondary purpose is to identify any other flutter/ LCO phenomena and comment upon.

5.3.1 Analysis of pod(s) influence, LCO case 1

Two flights were chosen to assess the influence of the pods on the LCO behavior. *Flight 2*: (see Table 1), an LCO prone external stores configuration (missiles on wing stations 1 and 9, GBU-24's on wing station 3 and 7 and external fuel tanks on wing stations 4 and 6, but without NAV pod and TGT pod). *Flight 10*: a nearly identical configuration with pods. Linear flutter analysis already showed for this kind of heavy store loading a severe aeroelastic instability within the required flight envelope (Ref. 9), which turned out to be an LCO during real flight conditions. Actually, Ref. 9 showed:
a severe instability for the configurations equipped with AIM-9's mounted on 16S210 launchers at wing stations 1 and 9, a more severe instability with AIM-9's on LAU-129 at wing stations 1 and 9 and a stable situation with AIM-120's on LAU-129 at wing stations 1 and 9.

Flight 2 recordings 4, 6, 8, 10, 12, and 14 were compared with flight 10 recordings 4, 6, 12, 14, 18, and 20 respectively. For each recording the 2-second PSD effective values of the tip accelerometers have been determined (see section 5.2.3.1 above), the values have been plotted as a function of the 2-second mean value of the Mach number.

The results of this analysis of the measured data showed an unexpected, significant influence of the pods: with pods LCO started at lower Mach numbers and identical g-levels were reached at Mach numbers lowered by about 0.05.

No firm conclusion about the reason could be drawn:
- the external store configurations were not exactly identical: in flight 2 a Standard Weapon Pylon (WPS) was attached to wing station 3, in flight 10 a Pylon Integrated Dispenser System (PIDS-3) was used,
- in flight 2 an ALQ-131 jammer pod was carried on the centerline station, while in flight 10 this station was empty,
- flight 10 was executed on 7 October 1999, flight 2 on 14 July 1999, and some changes in the FTI have been made in between (although a check did not reveal any inconsistencies),
- only 3 recordings were fully comparable (see table 2a).

In order to avoid any uncertainty, it was decided to repeat those flights. This took place on 26 June 2000. In flight 10a the external stores configuration of flight 10 was copied, in flight 10b the NAV pod and TGT pod were removed.

The selected recordings of flights 10a and 10b have been processed according section 5.2.3.1 above.

In Fig. 5 a 1-second time history of the wingtip accelerations of flight 10a recording 04 is given. The following observations are made:
- The signals contain a 4.5 Hz component; which is the LCO contribution, typical for this external store configuration and higher frequency components more related to buffet.

- The LCO component of AF01 and AF07 are roughly equal in magnitude and 180 deg out of phase, an anti-symmetrical phenomenon, again typical for this LCO case. The LCO component of AF02 and AF08 are smaller, and also out of phase.

In Fig. 6 the 2-second effective values of accelerations AF01 and AF07 are plotted as a function of Mach number. It is clear, that the correspondence in effective value of AF01 and AF07 is large. Further inspection reveals that this is also the case in the other recordings. Therefore, and because AF02/AF08 are smaller than AF01/AF07, the remainder of this analysis shall be based on AF01 only (worse condition).

In Fig. 7a the 2-second effective values of AF01 for both flights at 2000 ft with 2000 lbs fuel in the underwing tanks, are plotted as a function of the Mach number. Small differences can be seen. This observation also is valid for other altitudes and other underwing tank fuel states see e.g. Figs. 7b and 7c.

It is concluded that the presence of NAV pod and TGT pod has negligible effects on the flutter/ LCO behavior of this configuration.

5.3.2 Analysis of pod(s) influence, LCO case 2

Another LCO-prone configuration is with MK-84's on wing stations 3 and 7, and AIM-9 missiles on wing stations 1 and 9, and 2 and 8. Flight 7 was chosen to assess the influence of the NAV pod by comparison with flight test configurations, RACKS 17 and 20, from Ref. 7.
In Ref. 7 it is shown that in an identical configuration, but without the AIM-9 tip missiles, or with AIM-120's instead of AIM-9's on the wing tip locations, no LCO can be evoked. Flight 8 and 9 were chosen to check the validity of these results in presence of the NAV pod.

Flight 7.
Time history plots of recordings 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 of flight 7 were produced as per section 5.2.3.2 above. Next, they have been compared with the corresponding time histories of flight test configurations, RACKS 17/ 20, with MK-84’s on wing stations 3 and 7, AIM-9J missiles at wing stations 1, 2, 8, 9 and without NAV pod as reported in Ref. 7.
Small differences are observed between the results of the analyzed experimental data obtained during the flights of RACKS 17/20 (Ref. 7) and this flight 7. Therefore it is concluded once more, that the presence of the NAV pod has a negligible effect on the flutter/ LCO behavior of this configuration.

Flight 8.
In Fig. 8a the 2-second effective values of AF01 for the three flights at 2000 ft and 2000 lbs fuel in the underwing tanks, are plotted as a function of Mach number. It is clear from the figure, that LCO in flight 8 (no missiles at wing tip stations) is absent. This is also the case for other underwing tank fuel states and at other altitudes (plots not shown). The absence of LCO in flight 8 confirms earlier results obtained for the same configuration but without the NAV pod, flown as flight RACK 21, as reported in Ref. 7.

Flight 9
Fig. 8a shows that with AIM-120 missiles at the wing tip stations (flight 9) LCO does occur, be it at a much higher speed (1g effective at Mach 0.90 for flight 9 vs. Mach 0.63 for flight 7). Linear flutter analyses already show a favorable influence on the flutter stability with AIM-120 missiles on the wing tips, instead of AIM-9 missiles, as reported in Ref. 7.

Fig. 8b (FL100, 2000 lbs in underwing tanks) shows still some LCO for flight 9, in Fig. 8c (FL200, same underwing tank fuel state) LCO in flight 9 has disappeared.

The same LCO behavior is present in flight 9 with 1000 lbs fuel in the underwing tanks, but the peak levels are reduced by about 20 %. With empty underwing tanks the levels are further reduced by about 35 % to insignificant levels.

It is concluded that, contrary to earlier results, a configuration with AIM-120 missiles on the wing tip stations, MK-84's on 3 and 7 and full external tanks on wing stations 4 and 6, does produce LCO at low altitude. The magnitude of the LCO reduces at higher altitude and less fuel in the external tanks. In his post flight report the test pilot reported only very mild LCO, contrary to the above analysis results.

Since the presence of a NAV pod and TGT pod does not alter the LCO behavior of case 1 (see section 5.3.1 above) it is believed that the LCO behavior in flight 9 is also not altered by the presence of the NAV pod.

5.3.3 Other flutter/ LCO issues

A list has been made of all dedicated flutter/ LCO maneuvers in the period from July 1999 to October 1999. To this list the maneuvers have been added which were mentioned by the test pilot in his post flight report for unusual vibration behavior. Finally, maneuvers for other purposes were added to the list, which might evoke flutter or LCO.

For all flight/ recording numbers on the list the 2-second PSD effective values for the tip accelerometers have been tabulated as follows.

1. Any 2 second time segment with an effective (3 to 8 Hz) accelerometer value below 0.5 g is considered insignificant and is discarded.
2. Once an accelerometer value exceeds 0.5 g, the value is stored in normal font, together with the average segment time, Mach number, MA and velocity, CAS.
3. As in 2 but for 0.7071 g; the value is stored as above, but in *italic* font.
4. As in 2 but for 1.0 g; the value is stored as above, but in **bold** font.
5. As in 2 but for 1.4142 g; the value is stored as above, but in **yellow, bold** font.
6. As in 2 but for 2.0 g; the value is stored as above, but in **red, bold** font.
7. The maximum value is stored with a font as above, depending on the value.

In Table 4 the results are given. For clarity the store configuration of the particular flight is added. Also, the pilot's comment from the post flight reports is copied together with the analysis (interpretation) of the PSD plots.

A reasonable correlation can be found between the pilot's rating of the LCO magnitude and the calculated effective value of the resonance peak:

- For flights 2, 3, 4 and 10 the rating 'moderate' corresponds with an effective value of 1 g. The LCO frequency during these flights is around 4.5 Hz.
- For flight 7 the rating 'moderate' corresponds to a level tending towards a slightly higher value of 1.5 g. The LCO frequency during this flight is around 5.4 Hz.

Time history plots have been inspected for the 2-second effective acceleration exceedings in Table 4. The following remarks apply:

1. Flight 1 rec. 4 and 8: the configuration of flight 1 is highly identical to LCO case 1, section 5.3.1.

2. Flight 1 rec. 46: Light LCO for about 5 seconds, followed by broadband noise.
3. Flight 2: see LCO case 1, section 5.3.1.
4. Flight 3 rec. 10 and 12: broadband noise between 3 Hz and 10 Hz for about 20 seconds.
5. Flight 3a rec. 6 and 8: see 4 above.
6. Flight 4 rec. 4, 6 and 10 (a-symmetric loading): This is a download configuration of flight 1, viz.: no GBU-24 on the PIDS pylon at wing station 3. The LCO amplitude measured at the left wing tip is about twice as large as right. See also 2 and 3 above.
7. Flight 5 rec. 12, 14 and 44: broadband noise between 3 Hz and 12 Hz, see 4 above.
8. Flight 6 rec. 12 and 14 (wind up turn left and right, respectively): broadband noise between 3 Hz and 10 Hz, and between 30 Hz and 40 Hz.
9. Flight 7: see LCO case 2, section 5.3.2.
10. Flight 8: see LCO case 2, section 5.3.2.
11. Flight 9: see LCO case 2, section 5.3.2.
12. Flight 10: see LCO case 1, section 5.3.1.
13. Flight 11 rec. 12: broadband noise between 3 Hz to 12 Hz, see 4 above.
14. Flight 11 rec. 35: high buffet intensity between 30 Hz and 40 Hz due to sharp pull-up.
15. Flight 12 recordings 14 and 16 (wind up turn left and right, respectively): broadband noise between 3 Hz and 8 Hz, and between 30 Hz and 40 Hz.

5.4 Conclusion for Flutter and LCO

It has been shown for two flutter/ LCO prone external store configurations (flight 1, 2, 4, 7, 10, 10a, 10b) that the presence of a NAV pod and a TGT pod has negligible influence on the LCO behavior of the aircraft.

The presence of a NAV pod has negligible influence on the flutter stability of an already stable external store configuration (flight 8) without the NAV pod.

Contrary to earlier information the external store configuration of flight 9 showed light LCO, be it at low altitude and full underwing external fuel tanks.

Analysis of the other flights showed only broadband noise between 3 Hz and 10 Hz, and sometimes between 30 Hz and 40 Hz during windup turns and straight pull ups.

The analysis reported in Ref. 4, showed that most F-16 MLU configurations required by the RNLAF could be certified.
A few configurations required extra testing and one configuration: four AIM-9L's, two MK-84's with a PIDS-3 pylon at wing station 3, was tested and considered unacceptable and will not be certified.
The configuration: AIM-120 at wing stations 1,9 two GBU-24's at wing station 3,7, showed objectionable LCO damping characteristics above 475 KCAS with a PIDS-3 pylon at wing station 3 and also above 500 KCAS when flying with standard weapon pylon at wing station 3.
For the configuration: AIM-120 at wing stations 1, 9, GBU-24's at station 3,7, with a PIDS-3 pylon at wing station 3, it is recommended to limit the maximum airspeed to 475 KCAS below FL150.
For the configuration: AIM-120 at wing stations 1,9 GBU-24's at station 3,7, with a standard pylon at wing station 3 it is recommended to limit the maximum airspeed to 500 KCAS below FL150.

6 Left-hand pylon tank jettison results

Inlet mounted pods are likely to cause aerodynamic interference with stores in its proximity. In the case of the required RNLAF configurations, only non-jettisonable stores are carried at the centerline pylon, sta 5 (ALQ-131 or reconnaissance pod). Also only 370 gallon pylon tanks are required at the inboard wing pylons, sta 4 (LH) and sta 6 (RH). (See example of a configuration in Fig. 1.) Assessment of the separation behavior of these stores showed that separation of wing mounted tanks can be critical. Therefore the separation behavior of wing mounted tanks was investigated.

Tank separations are particular critical, because the pylon and tank are integrated into one unit, hence will release as one unit. To control separation up to a certain extent, there is a hinge between the rear-upper end of the pylon and the wing. This enables the pylon tank to pitch nose-down first. At 10 or 11 degree the pylon tank can fall free from the hinge.

Separation limits for tanks on the right hand inboard wing position (RH, sta 6) (with a LANTIRN targeting pod on the right hand inlet station (sta 5R)) have been well established for the F-16C/D versions (Refs. 10, 11 and 12). Hence for the F-16MLU the separation limits have been cleared on basis of similarity.

The Falcon Owl NAV pod is new to the F-16. Analyses of available tank separation reports for several configurations with and without LANTIRN navigation and targeting pods revealed that these pods did hardly or not effect sta 4 or 6 tank separation behavior (Ref. 10). Therefore it was decided to restrict the flight test program to *checking* the separation of the left-hand tank at limits identical to the LANTIRN pod limits. The check would be carried out as a direct comparison between the separation behavior of the tank in an already qualified configuration without NAV pod, to the same configuration with NAV pod. The stores configurations and release test conditions were selected on basis of the analysis. Fig. 9 shows a side view of the tested configuration for Flight N1; Fig. 10 shows the front view before Flight N2. Table 5 shows the release conditions and the stores configuration of the three executed flights N1, N2 and N3. For these tests the aircraft was equipped with two store separation cameras in the left-hand wing tip missile launcher (Fig. 11).

6.1 Separation test results

After developing of the films, the relevant film frames were scanned and stored as bitmaps. The film frame references and tank reference points in each relevant film frame were digitized and finally a trajectory reconstruction program was applied.

The results of this post-flight analysis are presented as:

- two-view tank trajectory graphs and pylon top edge traces
- time histories of tank position changes (x, y, z) and attitude changes (Euler angles: psi, theta, phi) since initial tank release moment (time = 0 for last frame with no tank movement).

In the tank trajectory graphs the centerlines of the tank are represented by arrows at 0.05 seconds interval (film frame rate 200 frames per second). Fig. 12 shows the coordinate system used for the presentation of the separation results. It is emphasized here that the tank position is referenced not by the tank+pylon center-of-gravity, but by its projection on the centerline of the tank body.

Figs. 13 and 14 present the results of flight N1 (LAS19).
Figs. 15 and 16 present the results of flight N2 (LAS20).
Figs. 17 and 18 present the results of flight N3 (LAS22).
Figs. 13, 15 and 17 are results from the camera in the nose of the camera tip launcher.
Figs. 14, 16 and 18 are results from the camera in the tail of the camera tip launcher.

Figs. 19, 20 and 21 show tank attitude (Euler angles) and position time histories, relative to the initial (carriage) position. No corrections for aircraft response (roll-off, pitch and yaw) have been applied. Also no corrections are applied for wing tip (camera) oscillations.

No smoothing has been applied to the trajectory data. Irregularities are caused by the fact that the GBU-10 store between the film cameras and the separating tank, obscures the tank for a significant part. In cases that only about eight or less reference points are visible at only a small area of the tank and pylon, the accuracy of the position and attitude reconstruction is reduced.

The first flight took place with a configuration, which was not formally cleared for the intended release conditions. Tank release at M=0.9 / 550 KCAS is not allowed when a PIDS-3 pylon instead of a standard weapon pylon at sta 3 or 7 carries a load like the GBU-10.
Fig. 22 shows the physical result of this tank separation.

To check the PIDS-3 pylon effect, the next flight was planned to take place with a standard pylon.
Fig. 23 shows a post flight ventral fin strikingly resembling the ventral fin in Fig. 22.

Finally the reference flight manual configuration (i.e. Falcon Owl NAV pod deleted) was taken to the air. In flight N3 the ventral fin was hit again by the separating pylon tank.
Fig. 24 shows that the initial damage to the ventral fin is almost identical to the damage done to the fins in the flights N1 and N2.

A “pre-Block 40” ventral fin was used in this final flight. This explains the more severe damage of the ventral fin, due to the high aerodynamic load. The final condition of the ventral fin is illustrated in the post-flight picture Fig. 25. This type of damage is well-known from intensive low flying in Goose Bay operations. In future tank separation flight tests only use of the new ventral fins is highly recommended.

Since tank trajectories and ventral fin damages were identical, the objective of the program: “show, that inlet mounted pods do not affect the separation behavior of wing mounted tanks”, was met. However, the separations are obviously unsatisfactory. The problem is an issue for already certified configurations.

6.2 Discussion of results

Comparing the results of the three flights shows a great resemblance of the three separations. This is clearly shown when plotting the six results (three flights and two camera results per flight) in one figure (Fig. 26).

The resemblance between the second and the third separation was to be expected, based on the preflight analysis of Ref. 10. A better separation of the second separation, relative to the first, might be expected, because the configuration with PIDS-3 pylon at LEFT hand wing sta 3, in stead of the standard weapon pylon, has lower tank separation limits. Tank trajectory data of separations from a wing station adjacent to a PIDS-3 pylon, were not available at NLR.

In search for an explanation for the second ventral fin hit, three candidate reasons were identified:

- The NAV pod has a negative influence on the tank trajectory.
- Not the PIDS-3 pylon is cause of the low tank jettison limits as was concluded from USAF flight test programs, but the LH tank separations are different from RH tank separations.
- ECS exhaust (left side only) causes different airflow close to the fuselage, resulting in different tank (LH vs. RH) separations.

The last mentioned possibility is considered unlikely: the initial (pitch and roll) rotations of the tank are due to local tank-pylon - wing-sta3+store conditions. Only in the final stage of the separation process, when the tank aft end is close to the ventral fin, the ECS exhaust can possibly influence the tank, but up to that moment, other contributions are governing.

The ventral fin hit in the third flight (no targeting pod and no PIDS-3 but standard pylon) raises serious suspicion on the validity of many published tank separation release and jettison limits. Test programs with tanks released (only) from the RH wing, as usually is performed and as is also the case in Ref. 10 might not be representative for tanks released from the LH wing. NLR had previously expressed concern about the asymmetry of the 370 gallon fuel tank. A longitudinal rim is running along the complete cylindrical part of the tanks, on the left lower side, about 45 degrees from the lowest tank longitudinal line (Fig. 27). The rim possibly generates asymmetrical aerodynamic forces, which can create different tank trajectories for tanks released from LH and RH wings.

The RNLAF had informed SPO F-16 about the tank - ventral fin hits. As a result lower tank jettison and release limits were issued to the F-16 users. An example: the limits of the tested (and many other air-to-ground) configurations were lowered from M= 0.9 / 550 KCAS to M = 0.75 / 450 KCAS. Especially the M = 0.75 limit is probably rather conservative. Probably safe higher limits can be determined on the basis of analysis only.

6.3 Comparison of USAF and RNLAF tank separations

Fig. 26 shows that in releases N1, N2 and N3 there is apparently negligible initial roll. Only when the tank is almost vertically nose down, the tank seems to roll nose-inboard. This is most probably due to the fact that the definition of Euler angles psi, theta and phi are not “continuous”. At a pitch angle theta = +90 or -90 degree, psi and phi are undefined. In case a store pitches exactly through 90 degree, without rolling, the roll angle “switches” from 0 degree to 180 degree. With other large maximum pitch down angles the roll angle will show a (an apparent) big change and in many cases does even change sign. The yaw angle changes depend on the orientation of the vertical plane in which the store pitches. For example: in a simple 3D situation (centerline store, only moving in symmetry plane of aircraft), the Euler roll angle phi as well as the yaw angle psi, change from 0 degree to 180 degree (without actually rolling about its longitudinal axis). Both angles are synchronized. For other pitch planes, not parallel with X-axis chosen for initial store attitude, extremes for roll and yaw attitude and sign changes are out of phase.

In Fig. 28 the results from USAF (Ref. 10) flights FLT28, FLT67 and FLT54 are compared. The trajectory data was taken from Ref. 13. Yaw angle, roll angle and lateral displacement of LH and RH tanks should "roughly" be symmetrical (with reference to the aircraft plane of symmetry). The results are "mirrored" (by changing the sign) to be able to compare (below) directly with the releases N1, N2 and N3.

FLT28 is without inlet mounted stores. FLT67 was with (RH) TGT pod only; FLT54 was with (RH) TGT pod and (LH) LANTIRN NAV pod. The result show that for these RH tank releases the presence of the LH LANTIRN NAV pod has a negligible effect on (initial) tank trajectory.

Unfortunately, data is only available for the initial 0.175 second of the releases. Actually the separation is incomplete at the final data point. This is clearly illustrated in the separation pictures of Figs. 29, 30 and 31.

Fig. 32 shows that there are differences in initial roll angle for the RNLAF versus the USAF results. The USAF releases (FLT67, FLT54 and FLT28) show an initial roll outboard of about 25 degree, while, at about t=0.16 s the roll direction changes to inboard roll. The initial rolling outboard causes the pylon to get an "angle-of-attack", which is expected to generate an outboard-directed force on pylon+tank. The tank lateral displacements (Y) for all flights with inlet mounted pods are hardly different. The exception is FLT28, the basic configuration without inlet mounted pod. The consequence is that for all other flights, even for the basic RNLAF flight N3, without Falcon Owl NAV pod, the tail of the tanks will be more inboard, which means: closer to the ventral fin.

With only limited data available for this comparison, it is too early for conclusions.
However, if the asymmetry of the tank (the longitudinal rim along the cylindrical part of the low-left side of the tank) causes asymmetric aerodynamic forces on the tanks, these seem to be diminished by the presence of the LANTIRN targeting pod. The RH sta 6 tank has the rim on the inboard side, which is close to the wake of the LANTIRN pod. A LH sta 4 tank has the rim on the outboard side, while a navigation pod is on the inboard side (N1 and N2). The effect of the *smaller and better-shaped* pod is expected to be less in this case. Apparently in the N1, N2 and N3 cases, the effect is that the three releases show identical tank trajectories, independent of the presence of the navigation pod on the inboard side of the tank. The (probable) aerodynamic effect, due to the rim on the outboard side of the tank, apparently did not change by the navigation pod.

More effort is required to investigate LH versus RH tank trajectories (using newly acquired trajectory data), to confirm the preliminary conclusion that the asymmetry of the 370 gallon pylon tank causes significant different trajectories for LH and RH releases. Computational Fluid Dynamics analyses could be used to investigate the effect of the tank asymmetry. A wind tunnel test on a proper (representative) model of an asymmetric tank could be executed. Alternatively a few flight tests could be executed with identical configurations and at the same flight conditions, but tank releases from RH and LH wing stations.

6.4 Conclusions for wing pylon tank jettison

In the period from July 2000 to September 2000 three test flights have been executed in order to establish possible influence of inlet mounted pods on the separation behavior of 370 gallon wing pylon tanks. The tanks were released at identical flight conditions from the left wing in three different configurations of which two with the Falcon Owl pod. All three tanks made contact with the left ventral fin on the aft fuselage of the F-16 test aircraft in a comparable way.

The conclusions from the flight test results and the analysis are that:

- The Falcon Owl navigation pod does not significantly change the trajectories of the released 370 gallon pylon tanks.
- Adding the Falcon Owl pod does not affect the tank jettison limits.
- The 370 gallon tank released from the left wing of a certified configuration without the Falcon Owl navigation pod, struck the ventral fin in conditions under which a previous, USAF certification flight test program showed a clean tank separation from the right wing.

Because a tank - ventral fin hit occurred with an already certified configuration, new tank jettison limits are issued by USAF/SPO/F-16. The limits for the RNLAF F-16A/B with the Enhanced Targeting Pod and the Falcon Owl navigation pod will (generally) be the same as the new limits for the comparable LANTIRN pod configurations.

The investigation into the left tank - ventral fin interference problem is a separate task, not related to the Falcon Owl pod, and of a general concern to the F-16 user community. Initial comparison of left hand and right pylon tank releases, indicates that there is a difference in tank separation trajectories for LH and RH tanks. In case the new issued release limits are considered too low, analyses and tests are required to improve the understanding of tank release behavior and establish improved release limits.

7 Conclusions

The Royal Netherlands Air Force and NLR carried out an analysis and test program with the F-16A/B for the airworthiness certification of the Lockheed Martin Overseas Corporation "Enhanced Targeting Pod" and the British Aerospace Systems "Falcon Owl" navigation pod.

Analysis of the effects of the pod on the loading of the aircraft in the external stores configurations and under the operational conditions showed no overload cases.
Ventral fins were instrumented to investigate loads and vibrations due to the addition of inlet mounted pods. Comparison of configurations with the navigation pod or targeting pod, with configurations without the pods, showed an increase in vibration levels; the most on the TGT pod side. As a consequence the chance of fatigue damage to the ventral fins will increase.

Flight handling was analyzed and did show that the impact of the pod(s) on the departure sensitivity was minimal within the defined operational envelope of the aircraft.
To verify the analysis test flights in "worst case" external store configurations, without and with pods, were dedicated to verifying the flight handling characteristics. The results confirmed the analysis; in general they were judged "satisfactory". Configurations with substantial asymmetric loads showed unacceptable flying qualities when rolling maneuvers were initiated at negative normal load factor (inverted flight). However, such operations are excluded in the aircraft's flight manual

Simulations and earlier flight test results were used to analyse flutter and Limit Cycle Oscillation (LCO) behavior. These tests served a dual purpose. Its first purpose was to validate the models, used for the analysis; its second purpose was to verify predicted behavior for worst case configurations and flight conditions. Flight tests were carried out to complement the analysis results.

In general the presence of a navigation pod has negligible influence on the flutter and LCO behavior. The tests of the worst case situation resulted in the following limits:

- The configuration: four AIM-9L's, two MK-84's with a PIDS-3 pylon at wing station 3 was tested and considered unacceptable and will not be certified.
- The configuration: AIM-120 at wing stations 1,9, two GBU-24's at wing station 3,7, showed objectionable LCO damping characteristics above 475 KCAS with a PIDS-3 pylon at wing station 3 and also above 500 KCAS when flying with a standard weapon pylon at wing station 3.
- For the configuration: AIM-120 at wing stations 1, 9, GBU-24's at station 3,7, with a <u>PIDS-3</u> pylon at wing station 3, it is recommended to limit the maximum airspeed to 475 KCAS below FL150.
- For the configuration: AIM-120 at wing stations 1,9 GBU-24's at station 3,7, with a <u>standard</u> pylon at wing station 3 it is recommended to limit the maximum airspeed to 500 KCAS below FL150.

Simulations and results from earlier tank separation tests (USAF and RNLAF) were used to estimate the effects of pods on tank separations. On basis of the analysis it was concluded that the effects would be minimal and that safe separations could be demonstrated by direct comparison of pod configurations with already certified configurations.

Three test flights have been executed to establish possible influence of inlet mounted pods on the separation behavior of 370 gallon wing pylon tanks. The tanks were released at identical flight conditions from the left wing in three different configurations of which two with the Falcon Owl pod. All three tanks made contact with the left ventral fin on the aft fuselage of the F-16 test aircraft.
The tests and analyses showed that:

- The Falcon Owl navigation pod does not significantly change the trajectories of the released 370 gallon pylon tanks.
- Adding the Falcon Owl pod does not affect the tank jettison limits.
- The 370 gallon tank released from the left wing of a certified configuration without the Falcon Owl navigation pod, struck the ventral fin in conditions under which a previous, USAF certification flight test program showed a clean tank separation from the right wing.
- Because of the left tank - ventral fin interference problem new tank jettison limits are issued by USAF/SPO/F-16. The new limits are adopted for the RNLAF F-16A/B with the Enhanced Targeting Pod and the Falcon Owl Navigation Pod.

The investigation into the left tank - ventral fin interference problem is a separate task, not related to the Falcon Owl pod, and is of a general concern to the F-16 user community. Initial comparison of left hand and right pylon tank releases indicates that there is difference in tank separation trajectories for LH and RH tanks. In cases where the new release limits are too low, more analyses are required to improve the understanding of tank release behavior and probably improve release limits.

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Appendix B: Flight test trajectory data.

Tables

Table 1 Tested heavy store configurations.

Flt	1	2	3	4	5L	5	5R	6	7	8	9
1	AIM-120		PIDS-3 GBU-24	PT		ALQ		PT	WPS GBU-24		AIM-120
2	AIM-120		WPS GBU-24	PT		ALQ		PT	WPS GBU-24		AIM-120
3, 3a	AIM-120	AIM-9L	PIDS-3 3 MK- 82LD	PT		ALQ		PT	WPS 3 MK- 82LD	AIM-9L	AIM-120
4	AIM-120		PIDS-3	PT		ALQ		PT	WPS GBU-24		AIM-120
5	AIM-120	AIM-9L	PIDS-3 3 MK- 82LD	PT	NAV	ALQ		PT	WPS 3 MK- 82LD	AIM-9L	AIM-120
6	AIM-120		PIDS-3	PT	NAV	ALQ		PT	WPS GBU-24		AIM-120
7	AIM-9L	AIM-9L	PIDS-3 Mk-84	PT	NAV			PT	WPS MK-84	AIM-9L	AIM-9L
8	LAU-129	AIM-9L	PIDS-3 MK-84	PT	NAV			PT	WPS MK-84	AIM-9L	LAU-129
9	AIM-120	AIM-9L	PIDS-3 MK-84	PT	NAV			PT	WPS MK-84	AIM-9L	AIM-120
10	AIM-120		PIDS-3 GBU-24	PT	NAV		TGT	PT	WPS GBU-24		AIM-120
11	AIM-120	AIM-9L	PIDS-3 3 MK- 82LD	PT	NAV	ALQ	TGT	PT	WPS 3 MK- 82LD	AIM-9L	AIM-120
12	AIM-120		PIDS-3	PT	NAV	ALQ	TGT	PT	WPS GBU-24		AIM-120
10a	AIM-120		PIDS-3 GBU-24	PT	NAV		TGT	PT	WPS GBU-24		AIM-120
10b	AIM-120		PIDS-3 GBU-24	PT				PT	WPS GBU-24		AIM-120

Table 2a Flight profile, flutter/ LCO; all: level acceleration.

Configuration			Flight number								
Altitude	Speed (1)	Fuel in tanks (lbs)	1	2	4	7	8	9	10	10a	10b
2000 ft	250 to 600KCAS/M1.0	2000	4	4 (3)	4 (4)	4	4	4	4	4	4
FL100	250 to 600KCAS/M1.0	2000		6		6	6	6	6	6	6
FL150	250 to 600KCAS/M1.0	2000							10		
FL200	250 to 600KCAS/M1.0	2000				8		8	8	8	8
2000 ft	250 to 600KCAS/M1.0	1000		8 (3)		10	8	10	12	14	14
FL100	250 to 600KCAS/M1.0	1000		10	6	12		12	14	12	12
FL200	250 to 600KCAS/M1.0	1000	8 (2)			14	10	14	16	10	10
2000 ft	250 to 600KCAS/M1.0	0		12 (3)		16		16	18	16	16
FL100	250 to 600KCAS/M1.0	0		14		18		18	20	18	18
FL150	250 to 600KCAS/M1.0	0							22		
FL200	250 to 600KCAS/M1.0	0				20		20			20
FL300	250 to 600KCAS/M1.0	0				21					

Remarks
1. Planned speed
2. Run made at FL180 with 1200 lbs fuel in tanks
3. Run made at 750 ft
4. Run made at 5000 ft, 1650 lbs fuel in tanks

Table 2b Flight profile, handling.

Flt	Rec	Alt	Speed KCAS	G's	type
1	10	FL180	350		Stick rap
1	12	FL250	350	5	Windup turn left
1	14	FL250	350	5	Windup turn right
1	46	FL250	M0.95	5.5	Straight pull
3	4	1000 ft			Level accel
3	8	FL100			Level accel
3	10	FL250	350	5	Windup turn right
3	12	FL250	350	5	Windup turn left
3	35	FL85	540	5.4	Straight pull
3a	6	FL250	350	5	Windup turn left
3a	8	FL250	350	5	Windup turn right
3a	40	FL90	M0.95	5.5	Straight pull
4	4	5000 ft	250-600		Level accel
4	6	FL100	250-600		Level accel
4	8	FL250	350	5	Windup turn left
4	10	FL250	350	5	Windup turn right
4	44	FL180	M1.2	5.5	Straight pull
5	12	FL250	350	5.5	Windup turn left
5	14	FL250	350	5.5	Windup turn right
5	44	FL90	550/M.95	5.5	Straight pull
6	12	FL250	350	5.5	Windup turn left
6	14	FL250	350	5.5	Windup turn right
11	12	FL250	350	5.5	Windup turn left
11	35	FL90	550/M.95	5.5	Straight pull
12	14	FL250	350	5.5	Windup turn left
12	16	FL250	350	5.5	Windup turn right
12	45	FL90	550/M.95	5.5	Straight pull

Table 3 Parameter list.

Parameter	Abbreviation	Unit	Range	Resolution	Samples/s
Mach number	MA	1	0.1 / 3.0	2.44 E-4	39
Calibrated airspeed	CAS-M	KT	50 / 1000	6.25 E-2	39
Throttle position	DTHR	1	0 / 1.3	3.00 E-4	78
Tip launcher accel L	AF01, AF02	g	-38 / 38	1.00 E-2	312.5
Tip launcher accel R	AF07, AF08	g	-38 / 38	1.00 E-2	312.5
pilot seat accelerations	AFSTY, AFSTZ	g	-12.6 / +12.6	1.40 E-2	312.5
Long. stick force	FSX	N	-198 / +198	8.90 E-2	312.5
Lateral stick force	FSY	N	-106 / +106	4.80 E-2	312.5
Pitch rate	RP	rad/sec	-1 / +1	3.83 E-4	78
Roll rate	RR	rad/sec	-5 / +5	2.62 E-3	78
Yaw rate	RY	rad/sec	-1 / +1	3.83 E-4	78
Lateral aircraft accel	AYP	g	-1.7 / +1.7	5.00 E-4	312.5
Vertical aircraft accel	AZP	g	-8.5 / +12.8	4.00 E-3	312.5

Table 4 Flutter/ LCO cases.

Flt	1	2	3	4	5L	5	5R	6	7	8	9
1	AIM-120		PIDS GBU-24	PT		ALQ		PT	WP GBU-24		AIM-120

Flt	Rec and maneuver	Comment	Par	T [sec]	Value [g]	CAS [kts]	MA [1]
1	4 Level accel, 2000ft, 1650lbs	Pilot: LCO, light (520/.81) to severe (580/.90) Analysis: LCO 4.3Hz	AF01	18342.3	0.543	554	0.850
				18346.3	*0.752*	562	0.862
				18356.3	**1.044**	574	0.880
				18362.2	**1.682**	587	0.901
				18370.2	**1.936**	581	0.893
			AF02	18360.2	0.539	583	0.893
				18362.2	*0.753*	587	0.901
				18366.2	*0.813*	593	0.909
			AF07	18278.1	*0.948*	472	0.722
				18358.3	**1.130**	578	0.886
				18362.2	**1.602**	587	0.901
				18370.2	**1.956**	581	0.893
			AF08	18296.3	*0.946*	506	0.773
				18364.2	*0.989*	592	0.907
	8 Level accel, FL180, 1200lbs	Pilot: LCO, light (460/.93) Analysis: LCO 4.5Hz	AF01	18788.2	0.504	458	0.935
			AF07	18788.2	0.509	458	0.935
	46 Straight pull, FL250, 5g	Analysis: LCO 4.7Hz, followed by broadband noise	AF01	19913.4	0.590	470	0.925
				19915.4	*0.726*	485	0.942
			AF02	19919.4	0.706	469	0.898
			AF07	19913.4	0.611	470	0.925
				19915.4	*0.760*	485	0.942
			AF08	19917.4	0.642	486	0.933
				19919.4	*0.972*	469	0.898

Flt	1	2	3	4	5L	5	5R	6	7	8	9
7	AIM-9L	AIM-9L	PIDS Mk-84	PT	NAV			PT	WP MK-84	AIM-9L	AIM-9L

Flt	Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
7	4 Level accel, 2000ft, 2000lbs	Pilot: LCO light (370) to moderate (400) Analysis: LCO 5.2Hz	AF01	750.6	0.508	386	0.608
				758.5	*0.722*	392	0.618
				774.5	**1.022**	401	0.633
				790.5	**1.151**	404	0.638
			AF02	756.5	0.541	390	0.616
				766.5	*0.735*	398	0.629
				792.5	*0.955*	400	0.631
			AF07	752.6	0.532	389	0.613
				760.5	*0.711*	393	0.620
				776.5	**1.022**	401	0.634
				790.5	**1.102**	404	0.638
			AF08	754.6	0.504	389	0.614
				764.5	*0.711*	397	0.627
				790.5	**1.008**	404	0.638
	6 Level accel, FL100, 2000lbs	Pilot: LCO light (370) to moderate (400) Analysis: LCO 5.3Hz	AF01	1199.8	0.515	386	0.690
				1205.8	*0.815*	384	0.687
				1209.8	**1.096**	387	0.693
				1213.8	**1.298**	391	0.7
			AF02	1201.8	0.520	384	0.688
				1207.8	*0.785*	385	0.690
				1211.8	**1.006**	389	0.697
				1219.8	**1.092**	392	0.703
			AF07	1201.8	0.571	384	0.688
				1205.8	*0.769*	384	0.687
				1209.8	**1.054**	387	0.693
				1213.8	**1.248**	391	0.7
			AF08	1201.8	0.554	384	0.688
				1207.8	*0.823*	385	0.690
				1211.8	**1.062**	389	0.697
				1219.8	**1.176**	392	0.703
	8 Level accel, FL200, 2000lbs	Pilot: LCO light (370) to moderate (400) Analysis: LCO 5.3Hz	AF01	1389.4	0.658	388	0.831
				1391.4	*0.861*	389	0.832
				1393.4	**1.041**	388	0.829
				1409.3	**1.287**	375	0.804
			AF02	1389.4	0.582	388	0.831
				1391.4	*0.766*	389	0.832
				1395.4	**1.086**	385	0.824
				1397.4	**1.132**	381	0.816
			AF07	1389.4	0.619	388	0.831
				1391.4	*0.805*	389	0.832
				1395.4	**1.123**	385	0.824
				1409.3	**1.234**	375	0.804
			AF08	1389.4	0.608	388	0.831
				1391.4	*0.790*	389	0.832
				1395.4	**1.081**	385	0.824
				1401.3	**1.173**	377	0.808

7 cont'd	Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
	10 Level accel, 2000ft, 1000lbs	Pilot: LCO light (370) to moderate (400) Analysis: LCO 5.3Hz	AF01	1873.4	0.532	373	0.585
				1947.4	*0.768*	384	0.603
				1953.3	**1.076**	383	0.602
				1995.3	**1.456**	392	0.615
				2005.3	**1.570**	389	0.611
			AF02	1949.4	0.527	383	0.603
				1957.3	*0.728*	383	0.602
				2003.3	**1.006**	396	0.622
				2005.3	**1.010**	389	0.611
			AF07	1873.4	0.515	373	0.585
				1947.4	*0.762*	384	0.603
				1953.3	**1.063**	383	0.602
				1995.3	**1.426**	392	0.615
				2001.3	**1.523**	396	0.621
			AF08	1947.4	0.573	384	0.603
				1951.4	*0.728*	383	0.603
				1991.3	**1.011**	387	0.608
				2005.3	**1.223**	389	0.611
	12 Level accel, FL100, 1000lbs	Pilot: LCO light (370) to moderate (400) Analysis: LCO 5.3Hz	AF01	2143.1	0.565	378	0.681
				2147.1	*0.716*	378	0.681
				2159.1	**1.041**	377	0.680
				2169.1	**1.489**	388	0.701
				2183.0	**1.744**	386	0.698
			AF02	2149.1	0.526	378	0.680
				2161.1	*0.726*	377	0.680
				2171.0	**1.063**	390	0.703
				2181.0	**1.185**	394	0.711
			AF07	2143.1	0.530	378	0.681
				2149.1	*0.738*	378	0.680
				2159.1	**1.009**	377	0.680
				2169.1	**1.444**	388	0.701
				2183.0	**1.683**	386	0.698
			AF08	2145.1	0.511	378	0.681
				2153.1	*0.722*	378	0.681
				2165.1	**1.006**	384	0.692
				2181.0	**1.420**	394	0.711
				2183.0	**1.452**	386	0.698
	14 Level accel, FL200, 1000lbs	Pilot: LCO light (370) to moderate (400) Analysis: LCO 5.4Hz	AF01	2407.4	0.575	379	0.816
				2411.4	*0.736*	378	0.815
				2419.4	**1.042**	379	0.816
				2433.4	**1.444**	380	0.819
				2491.3	**1.518**	409	0.734
			AF02	2409.4	0.512	379	0.815
				2415.4	*0.714*	378	0.815
				2427.4	**1.043**	380	0.819
				2489.3	**1.146**	407	0.739
			AF07	2407.4	0.540	379	0.816
				2413.4	*0.769*	378	0.814
				2421.4	**1.017**	378	0.815
				2489.3	**1.483**	407	0.739
			AF08	2407.4	0.521	379	0.816
				2413.4	*0.766*	378	0.814
				2421.4	**1.027**	378	0.815
				2435.4	**1.487**	378	0.813

7 cont'd	Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
	16 Level accel, 2000ft, 0lbs	Pilot: LCO light (380) to moderate (425) Analysis: LCO 5.5Hz	AF01	2874.6	0.514	384	0.600
				2904.6	*0.732*	405	0.632
				2916.6	**1.043**	422	0.659
				2946.5	**1.532**	447	0.697
				2956.5	**1.821**	454	0.708
			AF07	2872.6	0.504	383	0.598
				2888.6	*0.719*	387	0.605
				2916.6	**1.064**	422	0.659
				2946.5	**1.472**	447	0.697
				2966.5	**1.740**	434	0.677
			AF08	2916.6	0.525	422	0.659
				2932.5	*0.713*	431	0.672
				2954.5	**1.029**	451	0.703
				2956.5	**1.130**	454	0.708
	18 Level accel, FL100, 0lbs	Pilot: LCO light (380) to moderate (425) Analysis: LCO 5.5Hz	AF01	3068.3	0.631	397	0.711
				3070.3	*0.768*	396	0.710
				3076.3	**1.013**	397	0.712
				3102.3	**1.451**	425	0.761
				3110.3	**1.793**	418	0.75
			AF07	3068.3	0.616	397	0.711
				3070.3	*0.743*	396	0.710
				3078.3	**1.038**	398	0.713
				3102.3	**1.449**	425	0.761
				3110.3	**1.671**	418	0.75
			AF08	3074.3	0.552	396	0.710
				3100.3	*0.762*	422	0.756
				3110.3	**1.049**	418	0.750
	20 Level accel, FL200, 0lbs	Pilot: LCO light (380) to moderate (425) Analysis: LCO 5.6Hz	AF01	3222.2	0.530	391	0.842
				3224.2	*0.731*	393	0.845
				3228.2	**1.183**	397	0.853
				3232.2	**1.478**	400	0.859
				3238.2	**1.652**	397	0.851
			AF07	3222.2	0.545	391	0.842
				3224.2	*0.737*	393	0.845
				3228.2	**1.166**	397	0.853
				3232.2	**1.433**	400	0.859
				3238.2	**1.619**	397	0.851
			AF08	3228.2	0.598	397	0.853
				3230.2	*0.709*	399	0.856
				3240.2	*0.922*	395	0.847
	21 Level accel, FL300, 0lbs	Pilot: LCO light (350/.94) to very severe (365/.97) Analysis: LCO 5.6Hz	AF01	3254.2	**1.829**	390	0.838
				3256.2	**1.996**	384	0.828
				3390.1	**2.095**	363	0.959
			AF02	3386.1	0.563	366	0.964
				3388.1	0.668	367	0.969
			AF07	3254.2	**1.650**	390	0.838
				3256.2	**1.822**	384	0.828
				3390.1	**2.216**	363	0.959
			AF08	3254.2	**1.050**	390	0.838
				3256.2	**1.116**	384	0.828
				3388.1	**1.721**	367	0.969
				3390.1	**1.909**	363	0.959

Flt	1	2	3	4	5L	5	5R	6	7	8	9
8	LAU-129	AIM-9L	PIDS MK-84	PT	NAV			PT	WP MK-84	AIM-9L	LAU-129

Flt	Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
8	6 Level accel, FL100, 2000lbs	Analysis: broadband 5.5-40Hz	AF08	1169.3	0.601	535	0.940
	8 Level accel, FL200, 2000lbs	Analysis: broadband 4-40Hz	AF08	1702.0	0.604	592	0.928

Flt	1	2	3	4	5L	5	5R	6	7	8	9
9	AIM-120	AIM-9L	PIDS MK-84	PT	NAV			PT	WP MK-84	AIM-9L	AIM-120

Flt	Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
9	4 Level accel, 2000ft, 2000lbs	Analysis: peak 4.4Hz	AF01	1058.1	0.538	553	0.852
				1080.1	*0.804*	596	0.916
				1082.1	**1.265**	599	0.922
			AF02	1082.1	0.565	599	0.922
			AF07	1058.1	0.587	553	0.852
				1080.1	*0.801*	596	0.916
				1082.1	**1.207**	599	0.921
			AF08	1082.1	0.559	599	0.921
	6 Level accel, FL100, 2000lbs	Analysis: peak 4.5Hz	AF01	1268.7	0.540	516	0.908
				1270.7	0.575	523	0.919
			AF07	1268.7	0.512	516	0.908
				1270.7	0.553	523	0.919
			AF08	1274.7	0.552	534	0.938
	10 Level accel, 2000ft, 1000lbs	Analysis: peaks 4.4, 4.5Hz	AF01	1917.4	0.529	573	0.889
				1919.4	*0.891*	581	0.902
				1925.4	*0.920*	596	0.925
			AF02	1923.4	0.635	591	0.918
				1933.4	*0.732*	599	0.931
			AF07	1917.4	0.594	573	0.889
				1919.4	*0.882*	581	0.902
				1925.4	*0.987*	596	0.925
			AF08	1923.4	0.650	591	0.918
	12 Level accel, FL100, 1000lbs	Analysis: peak 4.5Hz	AF01	2067.9	0.509	522	0.917
			AF07	2067.9	0.503	522	0.917
	16 Level accel, 2000ft, 0lbs	Analysis: peak 4.5Hz	AF01	2656.9	0.584	597	0.918
			AF02	2654.9	0.564	592	0.911
			AF07	2658.9	0.525	591	0.909
				2662.9	0.601	573	0.883
			AF08	2656.9	*0.950*	597	0.918

Flt	1	2	3	4	5L	5	5R	6	7	8	9
10	AIM-120		PIDS GBU-24	PT	NAV		TGT	PT	WP GBU-24		AIM-120

Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
4 Level accel, 2000ft, 2000lbs	Pilot: LCO, light (520/.81) to moderate (540/.84) Analysis: LCO 4.4Hz	AF01	765.3	0.523	503	0.776
			791.3	*0.714*	532	0.819
			827.3	*0.992*	551	0.847
		AF02	807.3	0.504	541	0.833
			813.3	0.600	546	0.841
		AF07	765.3	0.518	503	0.776
			789.3	*0.710*	531	0.818
			821.3	**1.012**	549	0.845
			829.3	**1.063**	549	0.845
		AF08	809.3	0.506	545	0.839
			829.3	0.556	549	0.845
6 Level accel, FL100, 2000lbs	Pilot: LCO, light (460/.82) to moderate (475/.85) Analysis: LCO 4.5Hz	AF01	965.1	0.543	473	0.834
			977.1	*0.740*	491	0.865
			989.1	*0.849*	490	0.865
		AF07	965.1	0.538	473	0.834
			977.1	*0.715*	491	0.865
			989.1	*0.853*	490	0.865
8 Level accel, FL200, 2000lbs	Pilot: LCO, very light (430/.91) Analysis: LCO 4.6Hz	AF01	1116.8	0.544	427	0.900
			1120.8	0.663	440	0.924
		AF07	1116.8	0.516	427	0.900
			1120.8	0.673	440	0.924
10 Level accel, FL150, 2000lbs	Pilot: LCO, light (460/.89) to moderate (475/.92) to light (600/1.11) Analysis: LCO 4.5Hz	AF01	1170.7	0.547	465	0.888
			1176.7	*0.804*	472	0.894
			1182.7	*0.970*	486	0.916
		AF07	1170.7	0.549	465	0.888
			1176.7	*0.812*	472	0.894
			1182.7	*0.955*	486	0.916
		AF08	1188.7	0.541	504	0.948
12 Level accel, 2000ft, 1000lbs	Pilot: LCO, light (520/.81) to moderate (540/.84) Analysis: LCO 4.5Hz	AF01	1603.8	0.517	508	0.791
			1617.8	*0.834*	533	0.829
			1629.8	**1.047**	543	0.845
		AF02	1631.8	0.530	541	0.842
		AF07	1599.8	0.504	502	0.782
			1613.8	*0.738*	521	0.811
			1641.8	**1.022**	542	0.844
		AF08	1629.8	0.554	543	0.845
14 Level accel, FL100, 1000lbs	Pilot: LCO, light (460/.82) to moderate (475/.85) Analysis: LCO 4.5Hz	AF01	1767.2	0.517	449	0.792
			1805.1	*0.743*	482	0.849
			1821.1	*0.877*	488	0.861
		AF07	1767.2	0.519	449	0.792
			1805.1	*0.725*	482	0.849
			1821.1	*0.894*	488	0.861

10 cont'd	Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
	16 Level accel, FL200, 1000lbs	Pilot: LCO, very light (460/.89) Analysis: LCO 4.5Hz	AF01	1901.6	0.505	424	0.822
				1923.6	0.707	457	0.882
				1931.6	**1.015**	472	0.908
				1937.6	**1.074**	475	0.914
			AF02	1937.6	0.503	475	0.914
			AF07	1901.6	0.515	424	0.822
				1925.6	*0.733*	462	0.891
				1931.6	**1.030**	472	0.908
				1939.6	**1.078**	481	0.926
			AF08	1933.6	0.553	472	0.909
	18 Level accel, 2000ft, 0lbs	Pilot: LCO, light (520/.81) to moderate (540/.84) Analysis: LCO 4.5Hz	AF01	2261.5	0.626	514	0.800
				2273.5	*0.811*	548	0.853
				2277.5	**1.153**	560	0.870
				2279.5	**1.279**	558	0.868
			AF02	2277.5	0.513	560	0.870
				2279.5	0.558	558	0.868
			AF07	2261.5	0.627	514	0.800
				2273.5	*0.743*	548	0.853
				2277.5	**1.075**	560	0.870
				2279.5	**1.163**	558	0.868

10 cont'd	Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
	20 Level accel, FL100, 0lbs	Pilot: LCO, light (460/.82) to moderate (475/.85) Analysis: LCO 4.6Hz	AF01	2403.9	0.517	473	0.831
				2415.9	*0.724*	483	0.846
				2431.8	**1.040**	508	0.890
			AF07	2405.9	0.533	475	0.833
				2417.9	*0.708*	484	0.849
				2431.8	*0.998*	508	0.889
	22 Level accel, FL150, 0lbs	Pilot: LCO, light (460/.89) to moderate (475/.92) to light (600/1.11) Analysis: LCO 4.6Hz	AF01	2518.4	0.540	459	0.886
				2520.4	*0.762*	465	0.896
				2524.4	*0.860*	476	0.917
			AF07	2518.4	0.536	459	0.886
				2520.4	*0.737*	465	0.896
				2524.4	*0.827*	476	0.917
	24 Control sweep?	Pilot: LCO, very light (460/.89) Analysis: LCO 4.7Hz	AF01	2611.3	0.533	452	0.944

Flt	1	2	3	4	5L	5	5R	6	7	8	9
11	AIM-120	AIM-9L	PIDS 3 MK-82LD	PT	NAV	ALQ	TGT	PT	WP 3 MK-82LD	AIM-9L	AIM-120

Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
12 Windup turn left, FL250, 5.5g	Analysis: peak 3.4Hz (AF01/07), broadband 5.5-6.0Hz (AF02/08)	AF01	1515.3	0.546	347	0.833
			1517.3	*0.759*	343	0.820
		AF02	1513.3	0.584	352	0.848
		AF07	1517.3	0.689	343	0.820
		AF08	1517.3	*0.761*	343	0.820
35 Straight pull, FL90, 5.5g	Analysis: peak 3.4Hz (AF01/07), broadband 5.0-6.5Hz (AF02/08)	AF01	2519.0	0.671	496	0.916
		AF02	2519.0	**2.213**	496	0.916
		AF07	2519.0	**1.187**	496	0.916
		AF08	2519.0	*0.990*	496	0.916

Flt	1	2	3	4	5L	5	5R	6	7	8	9
12	AIM-120		PIDS	PT	NAV	ALQ	TGT	PT	WP GBU-24		AIM-120

Rec and maneuver	Comment	Par	T [sec]	eff [g]	CAS [kts]	MA [1]
14 Windup turn left, FL250, 5.5g	Analysis: peak 3.7Hz (AF01/07), 5.2Hz (AF02) and 6.6Hz (AF08)	AF01	19196.4	0.563	349	0.843
		AF02	19194.4	0.548	356	0.859
			19198.4	0.636	344	0.827
		AF07	19196.3	0.504	349	0.843
		AF08	19196.3	0.505	349	0.843
16 Windup turn right, FL250, 5.5g	Analysis: broadband noise	AF02	19248.6	0.591	347	0.825
		AF07	19252.6	0.597	348	0.803
		AF08	19244.6	0.537	355	0.854
			19248.6	0.652	347	0.825

Table 5

Release conditions and configurations RNLAF F-16B J-066 Flights N1, N2 and N3.

Conditions	**Flight N1**	**Flight N2**	**Flight N3**
Airspeed (M/KCAS)	0.899 / 550	0.900 / 550	0.899 / 551
Altitude (ft) hp =	5100	5200	4950
AOAboom (deg) =	1.8	1.9	1.8
ASSboom (deg) =	-0.3	-0.3	-0.3
Normal acc. (g) Az =	1.0	1.0	1.0

Configuration	**Flight N1**	**Flight N2**	**Flight N3**
sta 1 Cam Launcher	AMD	------	------
sta 2	------	------	------
sta 3 (pylon)	**(PIDS-3)** GBU-10	(std. pyl.) GBU-10	(std. pyl.) GBU-10
sta 4 (released)	370 gal. tank (empty)	370 gal. tank (empty)	370 gal. tank (empty)
sta 5L (LH inlet)	**Falcon Owl**	**Falcon Owl**	**------**
sta 5	ALQ-131	ALQ-131	ALQ-131
sta 5R (RH inlet)	**------**	**------**	**------**
sta 6	370 gal. tank (empty)	370 gal. tank (empty)	370 gal. tank (empty)
sta 7 (pylon)	(std. pyl.) GBU-10	(std. pyl.) GBU-10	(std. pyl.) GBU-10
sta 8	------	------	------
sta 9	------	AMD	CAT AIM-120

Figures

Fig. 1 The F-16B(MLU) test aircraft ("Orange Jumper") with "Enhanched Targeting Pod", "Falcon Owl Navigation Pod", ALQ-131, pylon tanks, GBU-24 and AMRAAM.

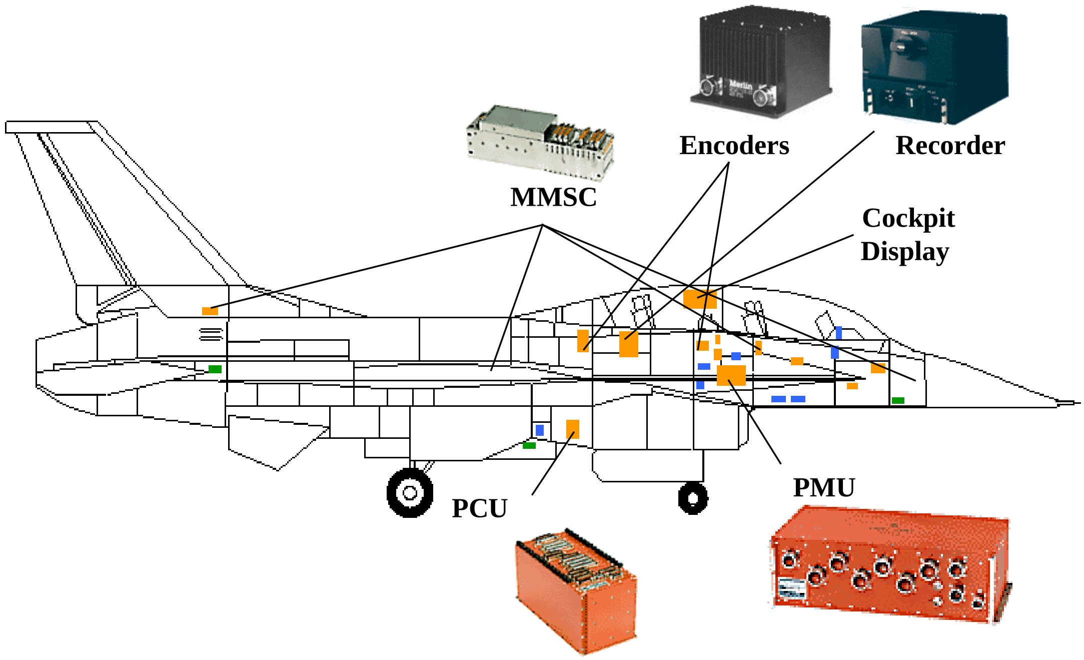


Fig. 2 Major locations of installed flight test instrumentation equipment.

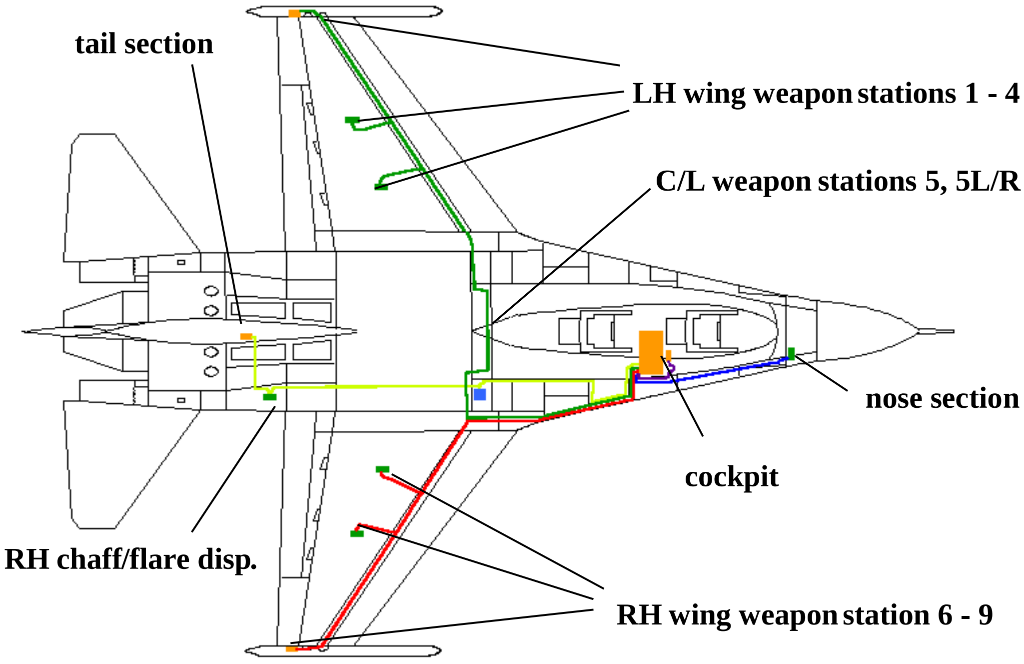


Fig. 3 Routing of the instrumentation data bus.

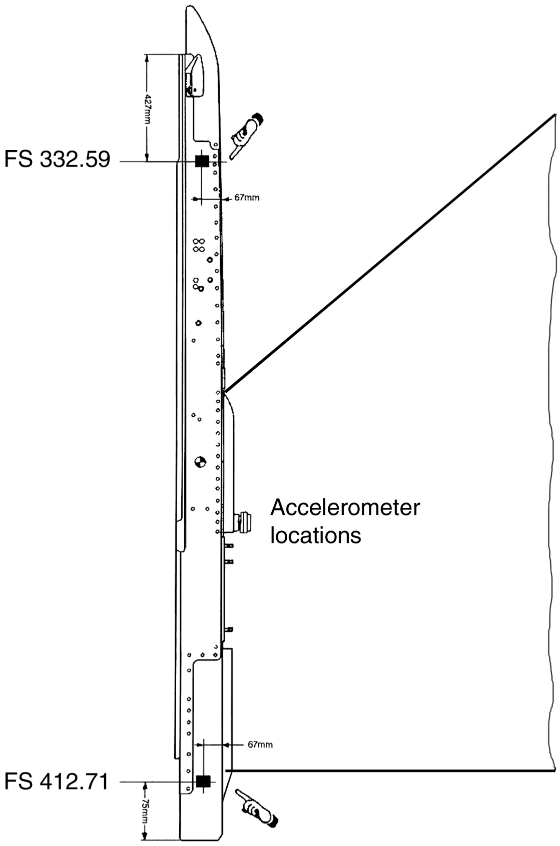
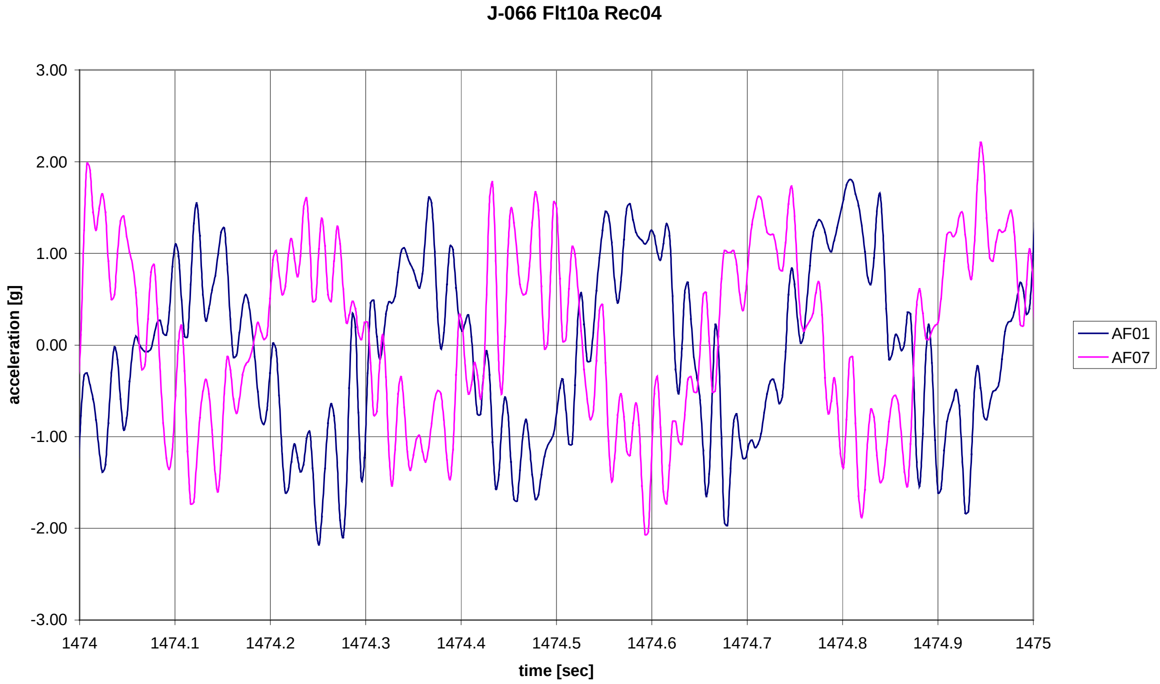


Fig. 4 Location of accelerometers in LH LAU-129 wingtip missile launcher; accelerations AF07 and AF08.
(AF01 and AF02 are from RH accelerometers.)



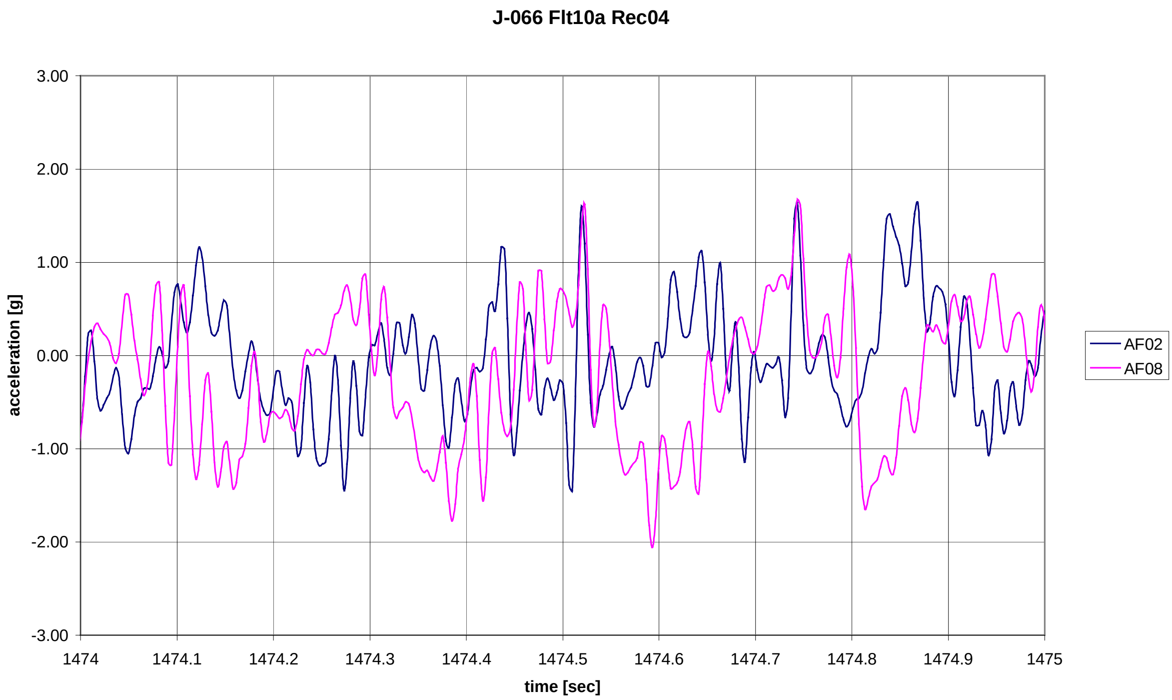


Figure 5 Time histories of wing tip accelerations AF01/AF07 and AF02/AF08 of flight 10a.

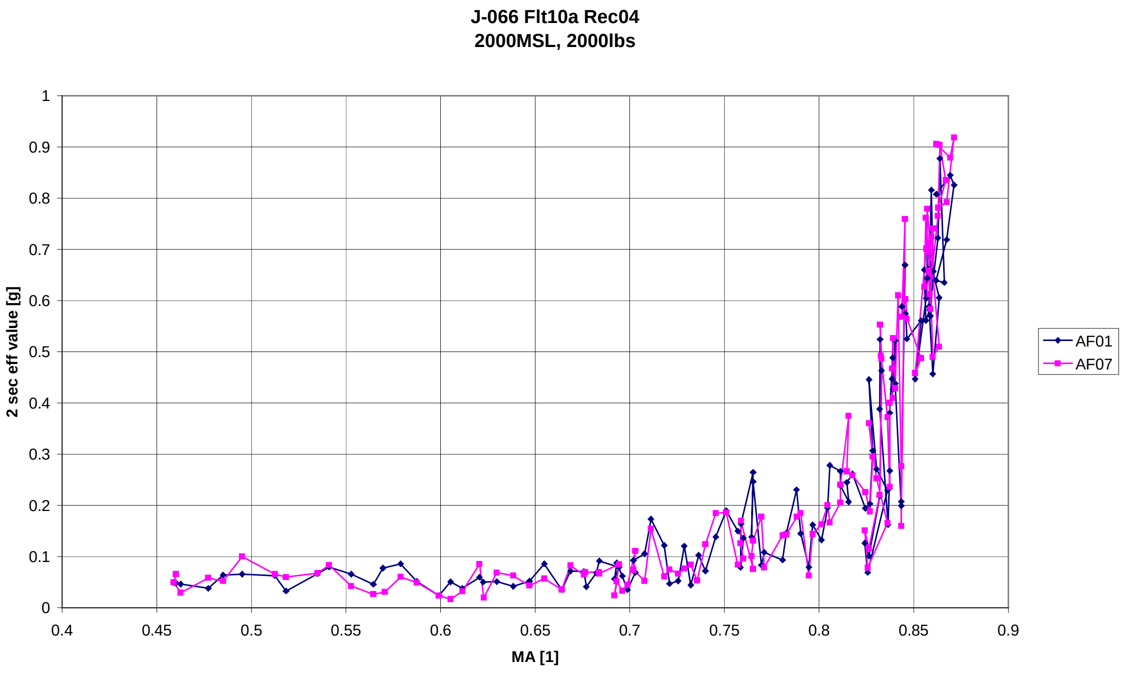


Fig. 6 Forward wing tip accelerations (AF01/AF07) as a function of Mach number (flight 10a).

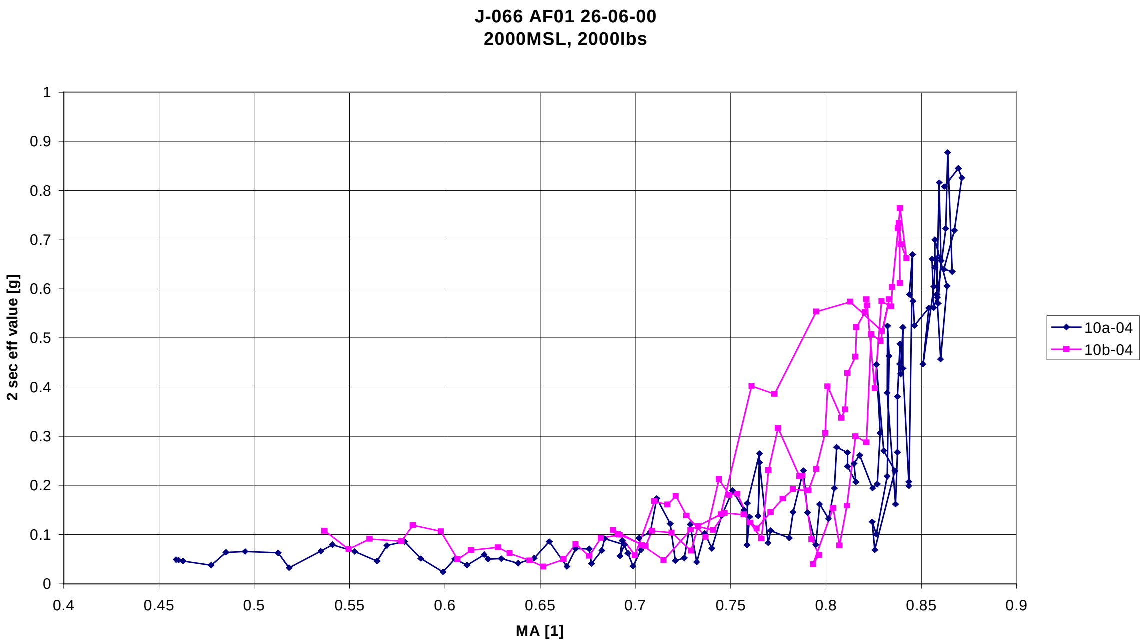


Fig. 7a Comparison of forward wing tip accelerations (AF01) of flights 10a and 10b as function of Mach number.

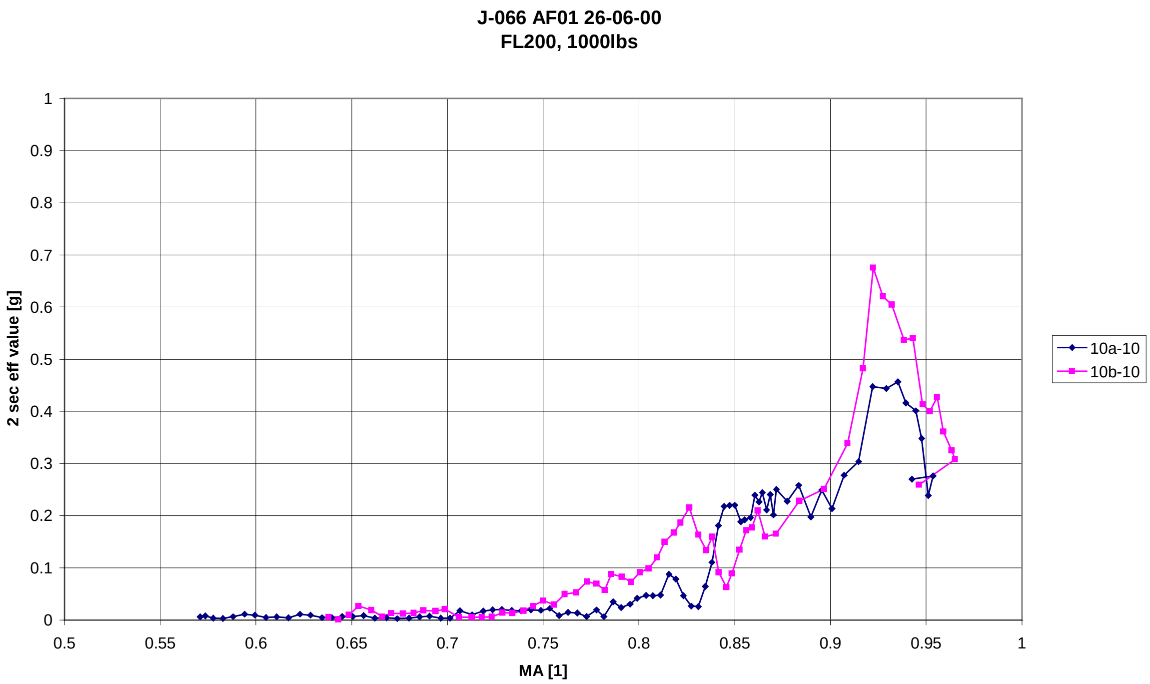


Fig. 7b Comparison of forward wing tip accelerations (AF01) of flights 10a and 10b as function of Mach number (continued).

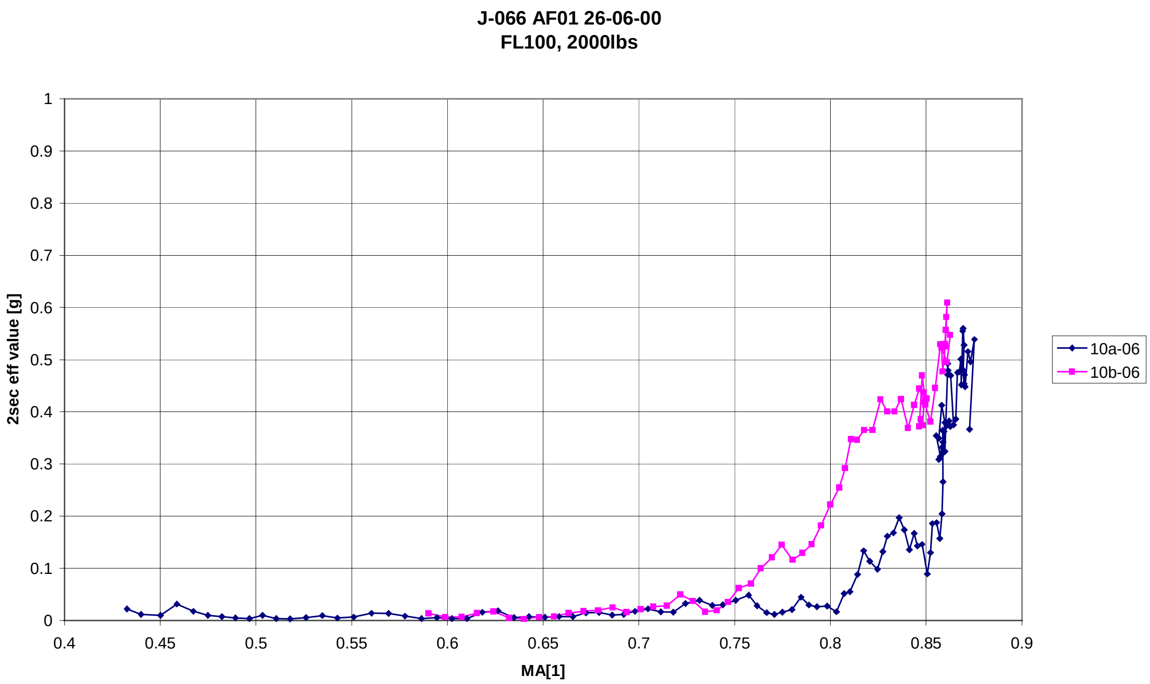


Fig. 7c Comparison of forward wing tip accelerations (AF01) of flights 10a and 10b as function of Mach number (continued).

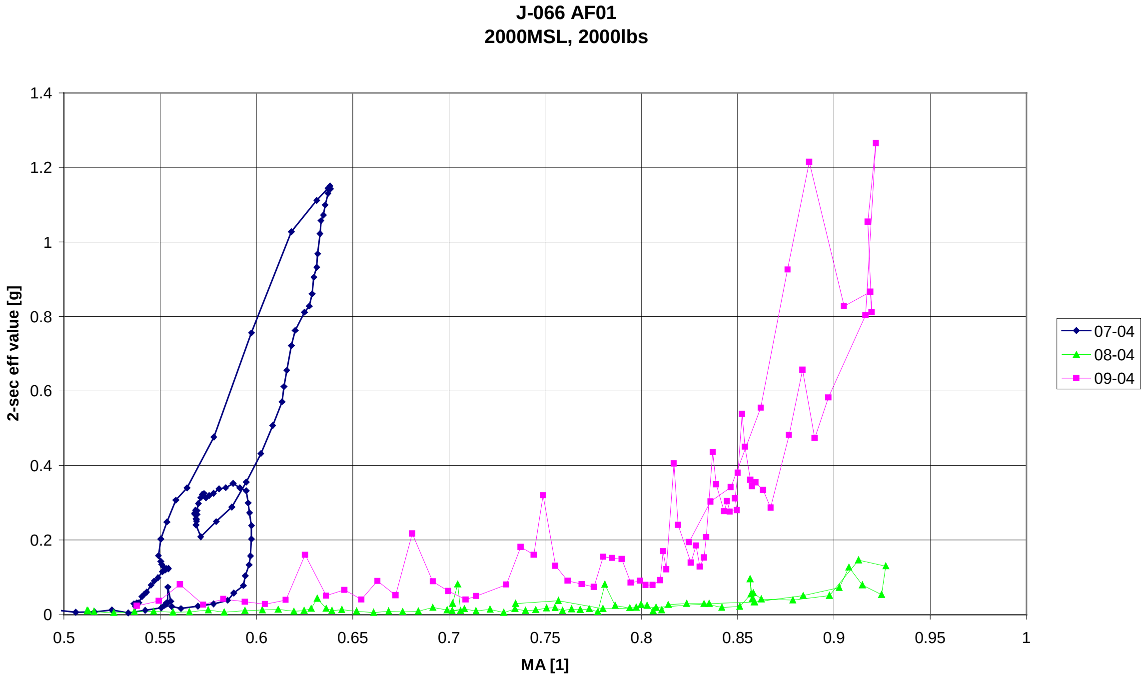


Fig. 8a Comparison of wing tip accelerations (AF01) of flights 7, 8, and 9 as function of Mach number.

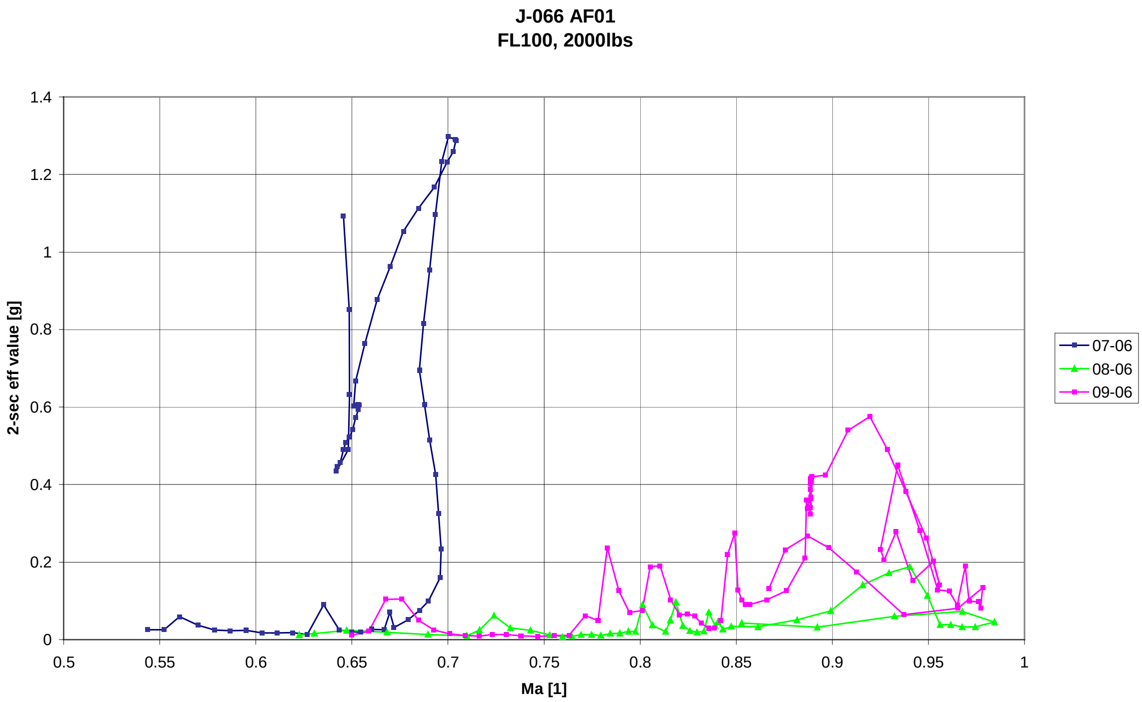


Fig. 8b Comparison of wing tip accelerations (AF01) of flights 7, 8, and 9 as function of Mach number (continued).

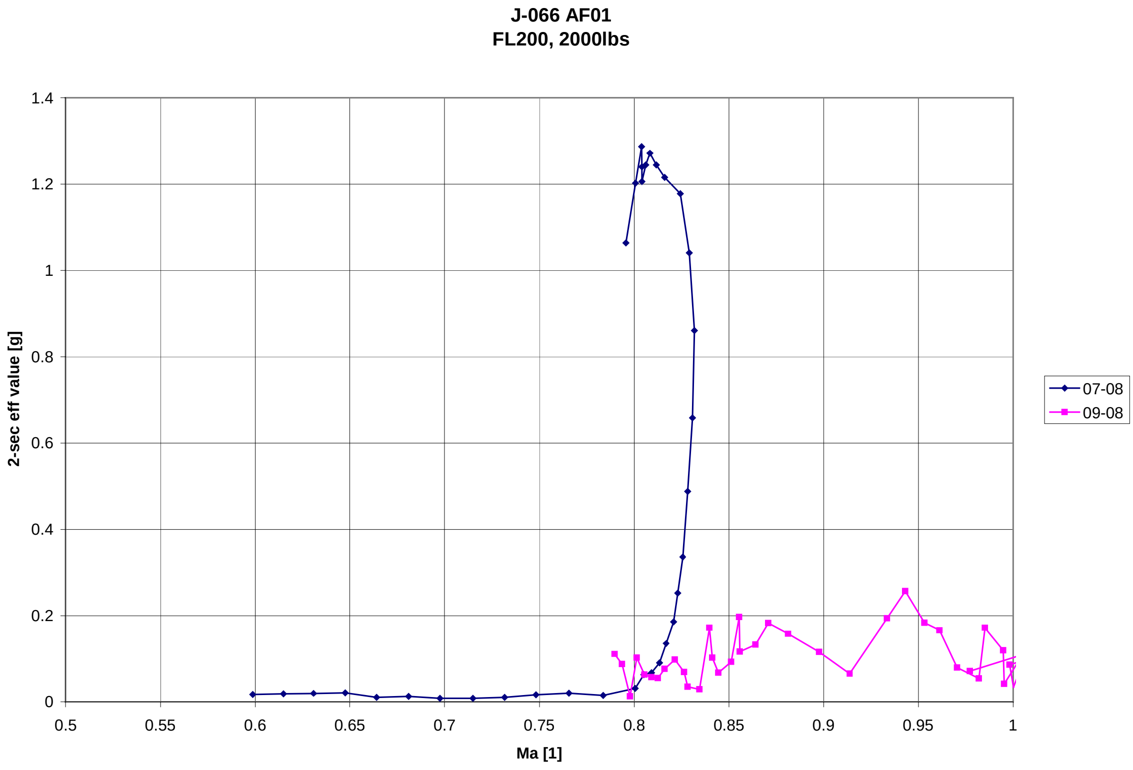


Fig. 8c. Comparison of wing tip accelerations (AF01) of flights 7 and 9 as function of Mach number (continued).

Fig. 9 RNLAF F-16B (J-066) test aircraft with Falcon Owl navigation pod at sta 5L (Flight N1).

Fig. 10 F-16B (J-066) test aircraft of before RNLAF flight N2.

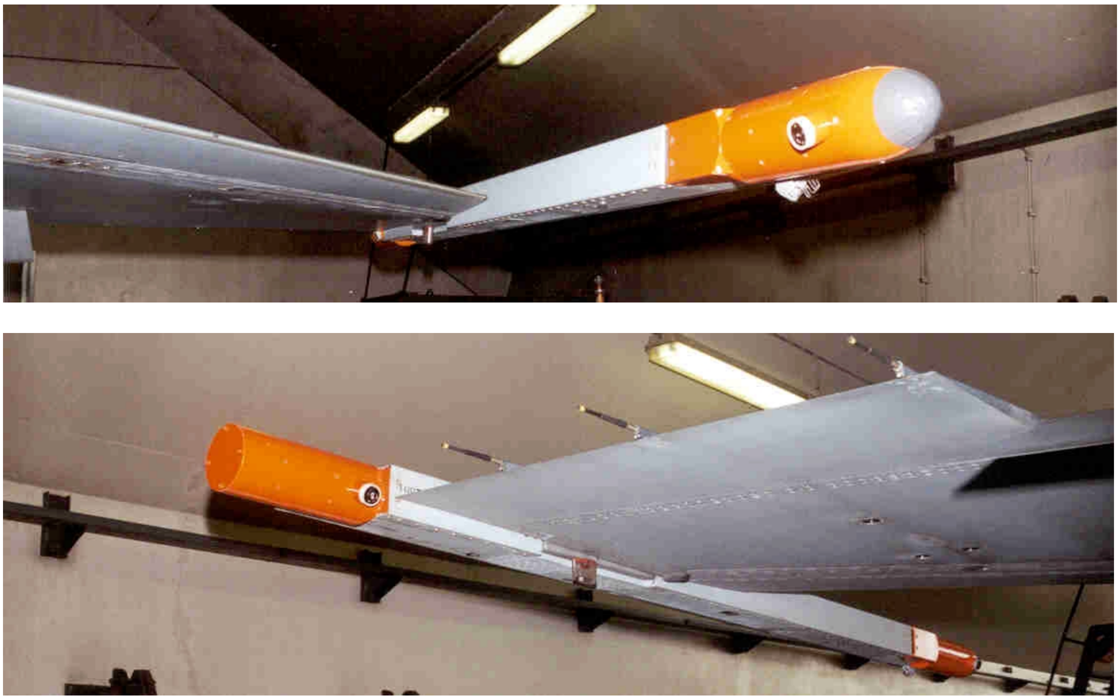


Fig. 11 High speed film cameras in modular installations on a LAU-129 launcher.

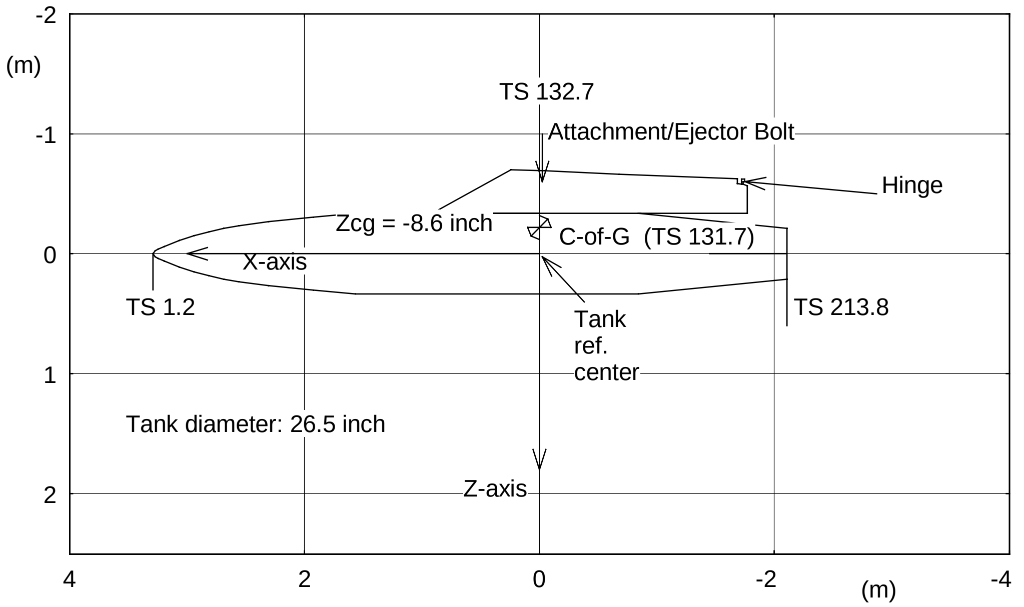


Fig. 12 Coordinate axis system used in this publication for presenting tank position time histories. The coordinate system is aircraft-fixed. When the tank separates, the position of the “tank-reference-center” is used to represent the tank position. The “tank-reference-center” is the projection of the Center-of-Gravity on the tank body centerline, which coincides with the origin before tank release.

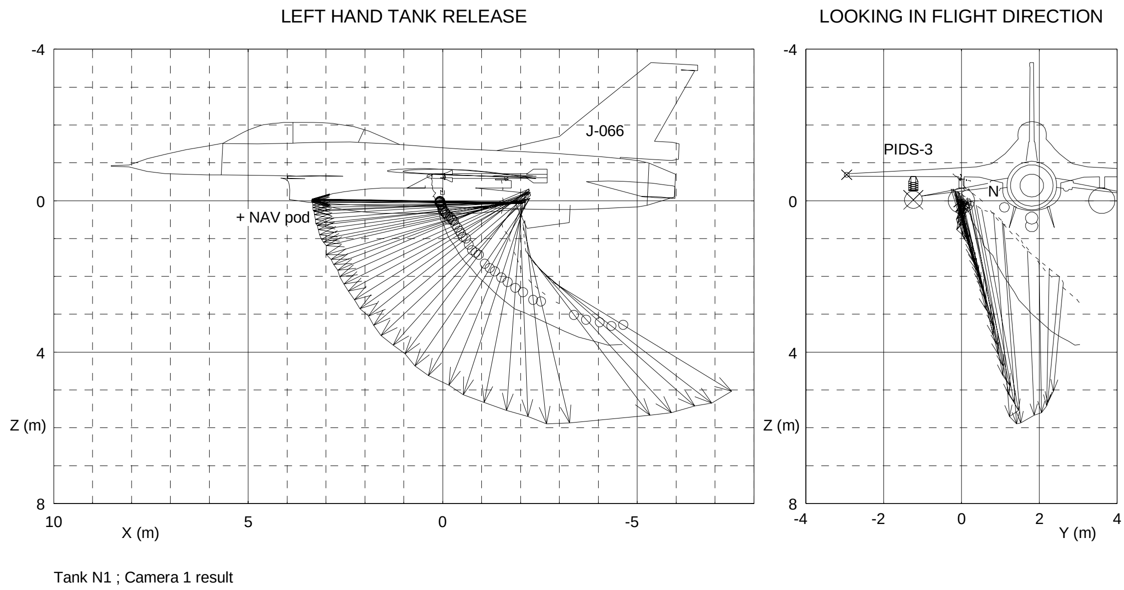


Fig. 13 Separation of 370 gallon tank from (LH) sta 4
RNLAF Flight N1, Camera 1 result

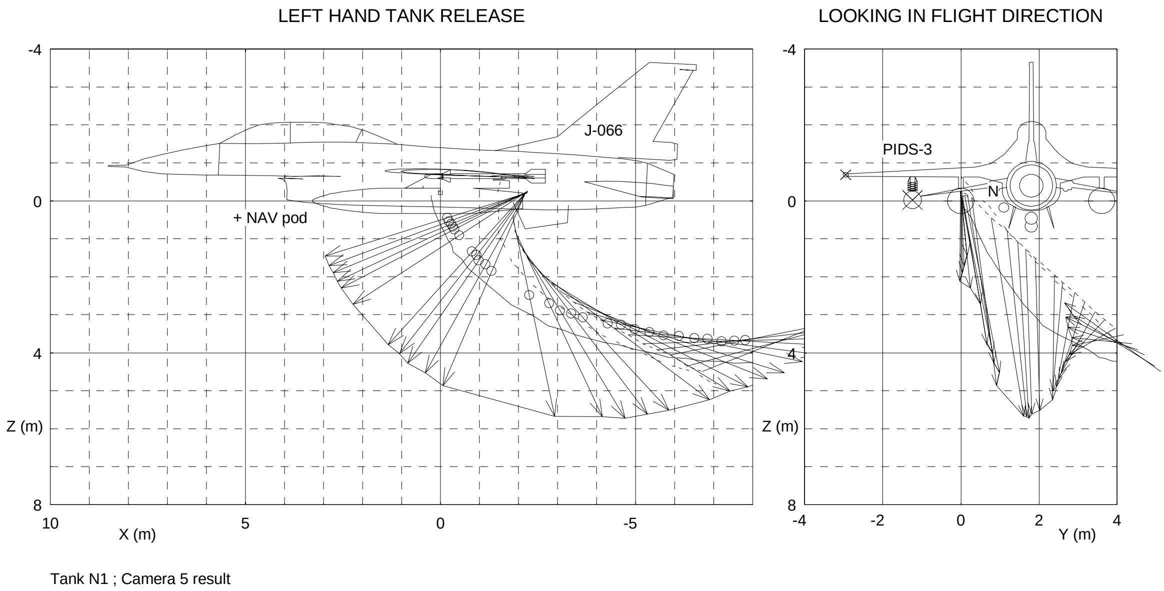


Fig. 14 Separation of 370 gallon tank from (LH) sta 4
RNLAF Flight N1, Camera 5 result

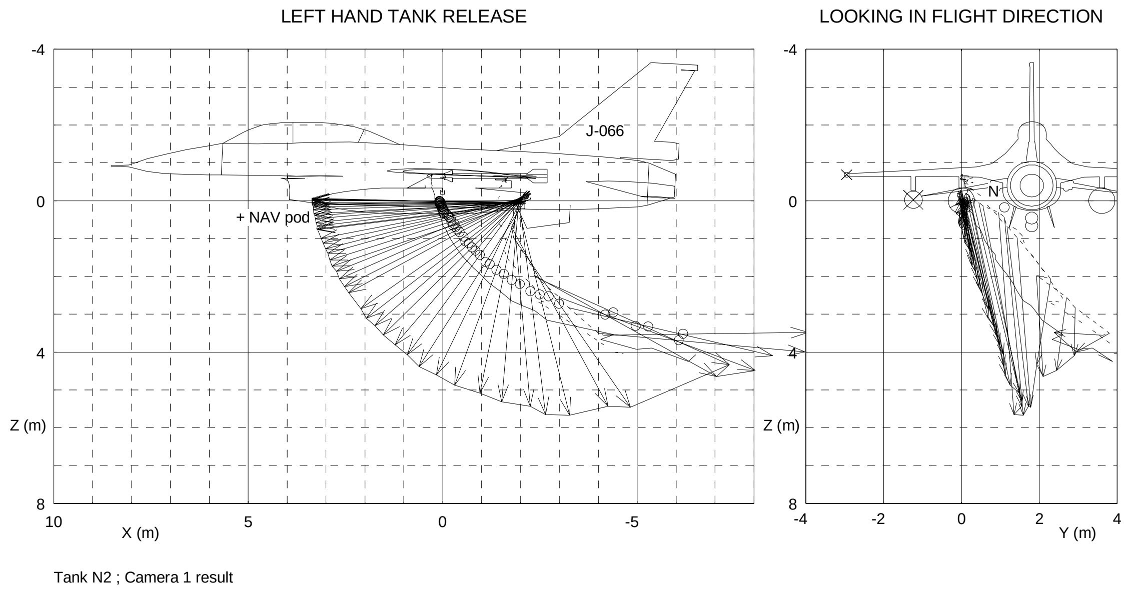


Fig. 15 Separation of 370 gallon tank from (LH) sta 4
RNLAF Flight N2, Camera 1 result

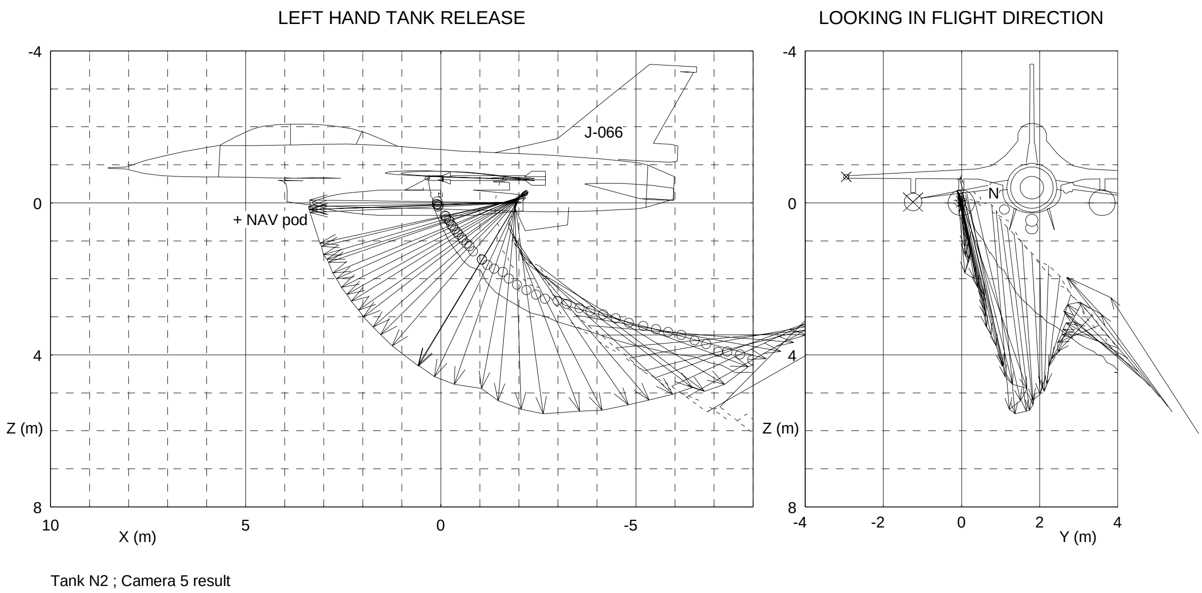


Fig. 16 Separation of 370 gallon tank from (LH) sta 4
RNLAF Flight N2, Camera 5 result

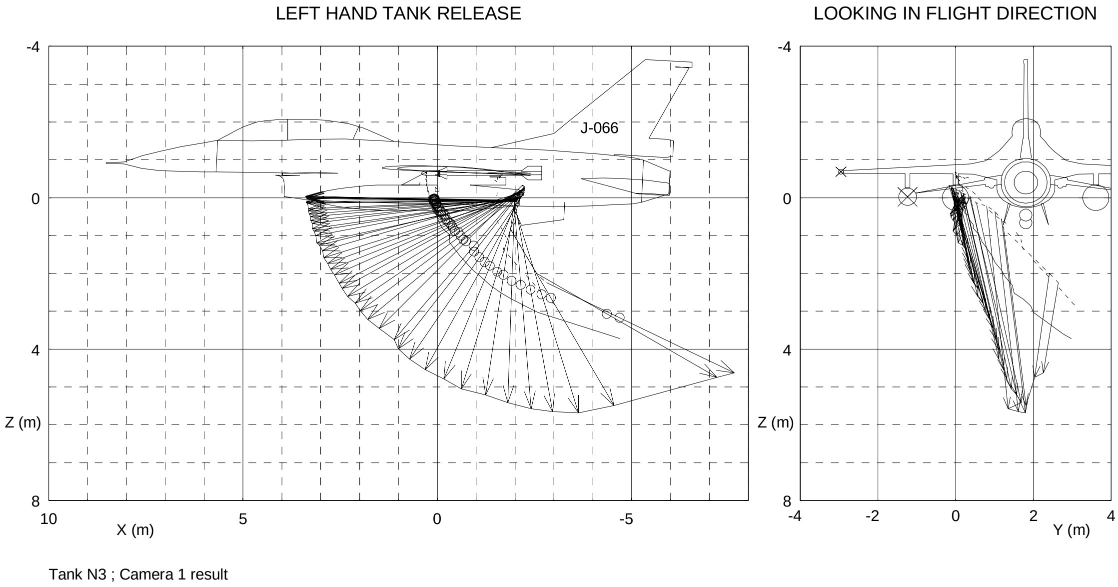


Fig. 17 Separation of 370 gallon tank from (LH) sta 4
RNLAF Flight N3, Camera 1 result

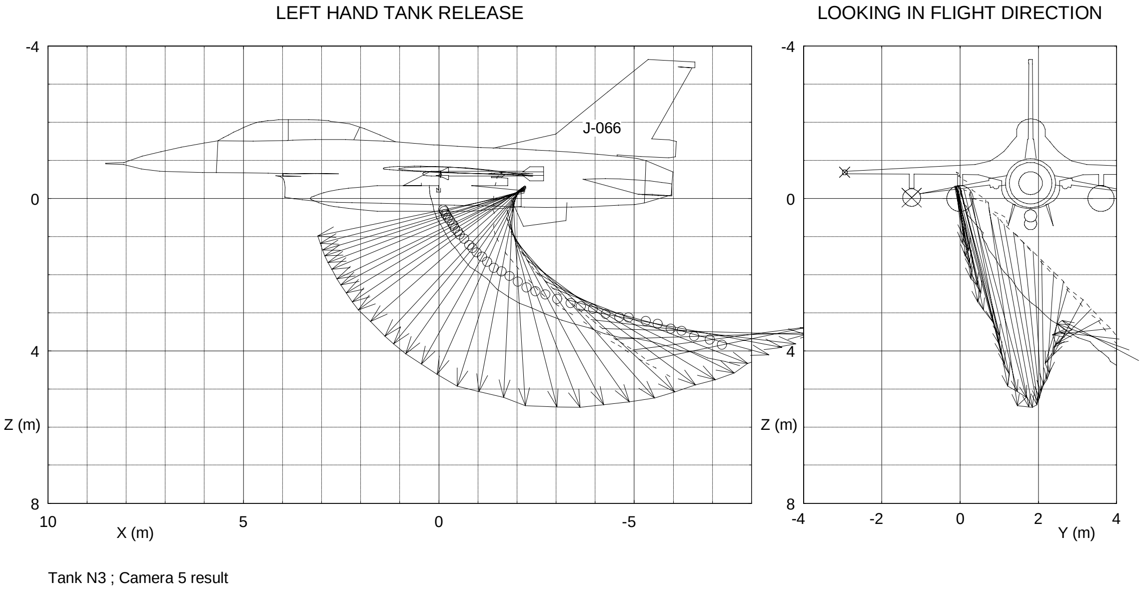


Fig. 18 Separation of 370 gallon tank from (LH) sta 4
RNLAF Flight N3, Camera 5 result

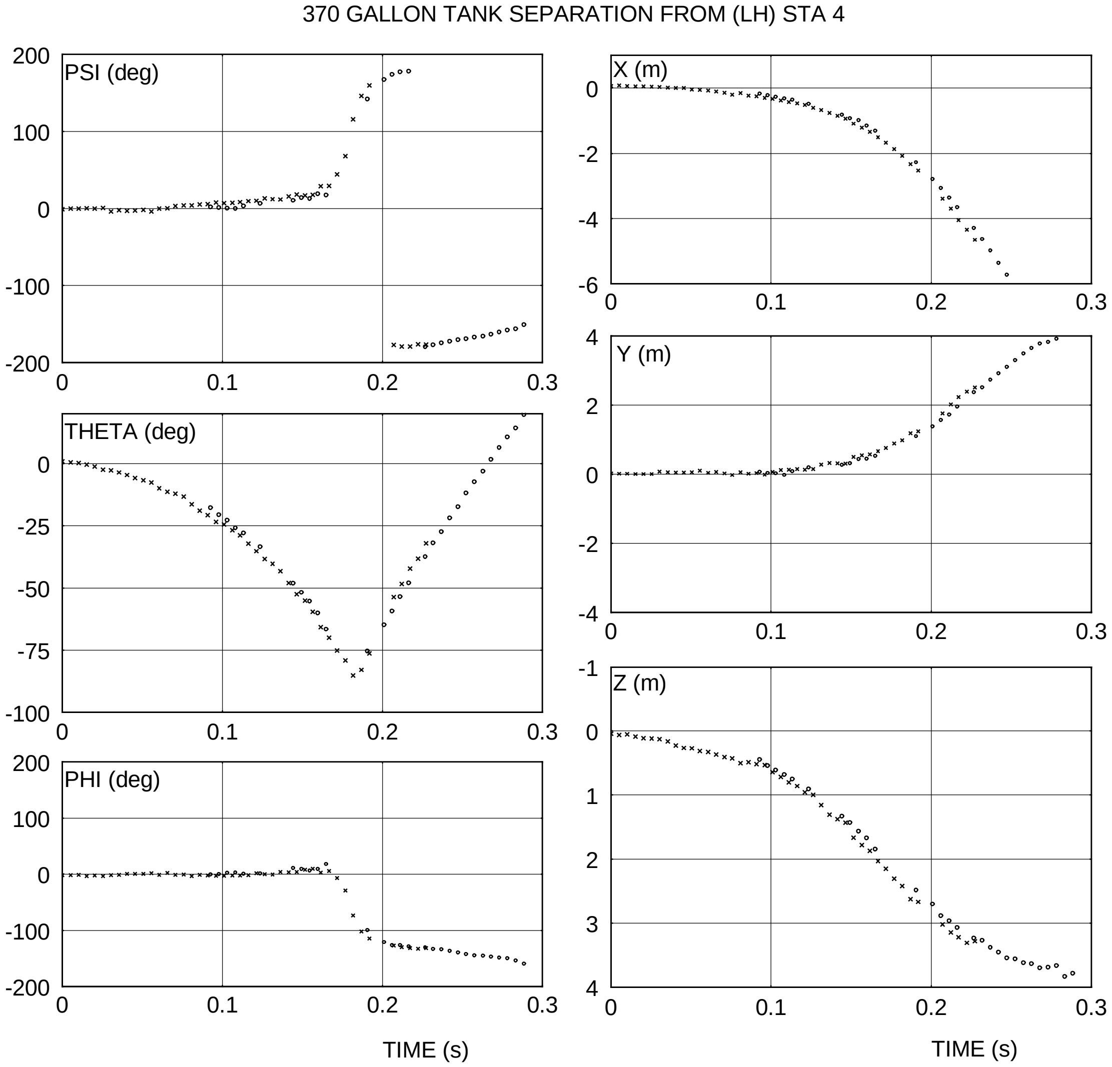


Fig. 19 Tank attitude and position time-histories (see Fig. 20).
RNLAF Flight N1, Results of both cameras combined.

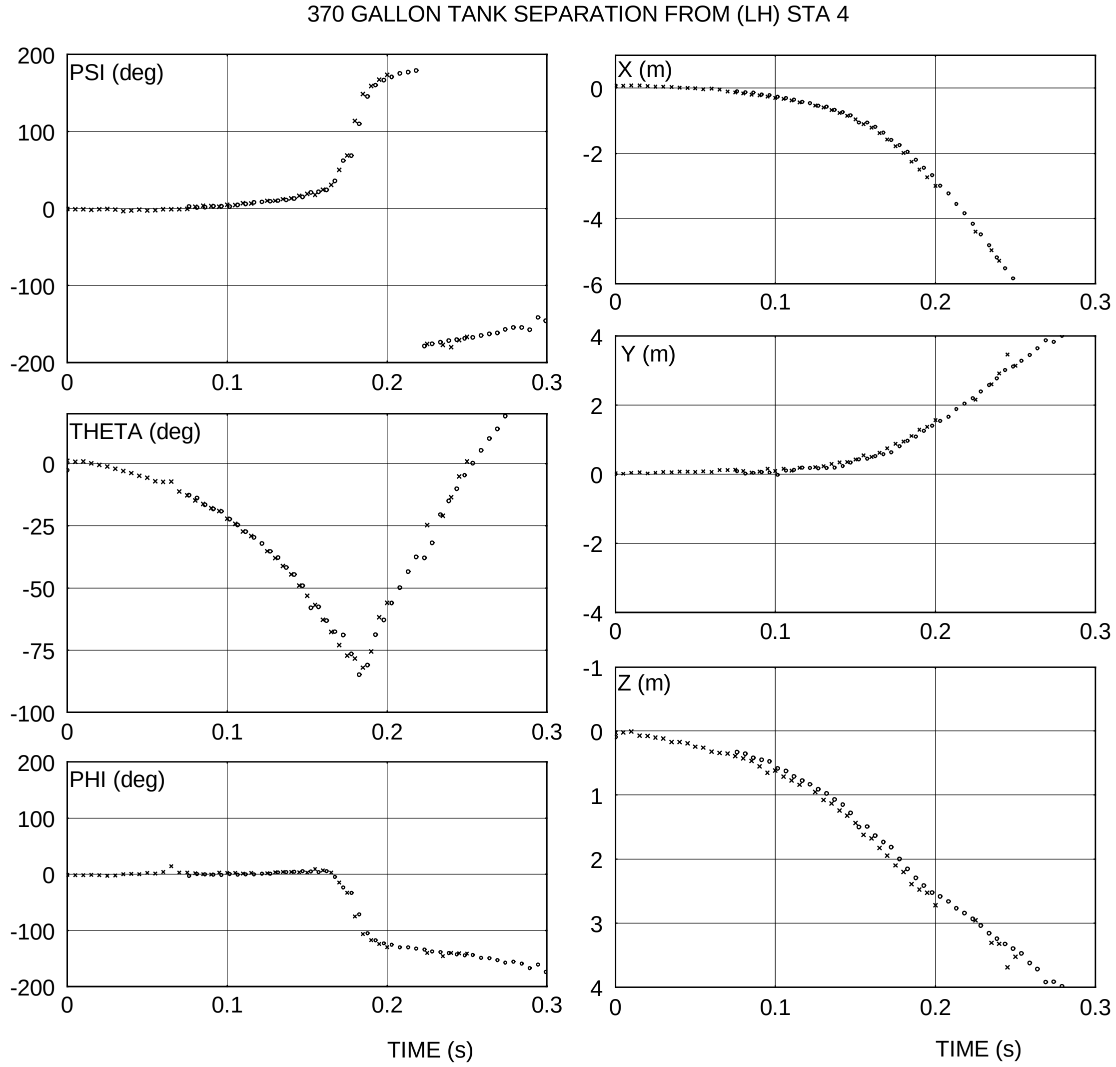


Fig. 20 Tank attitude and position time-histories (see Fig. 20).
RNLAF Flight N2, Results of both cameras combined.

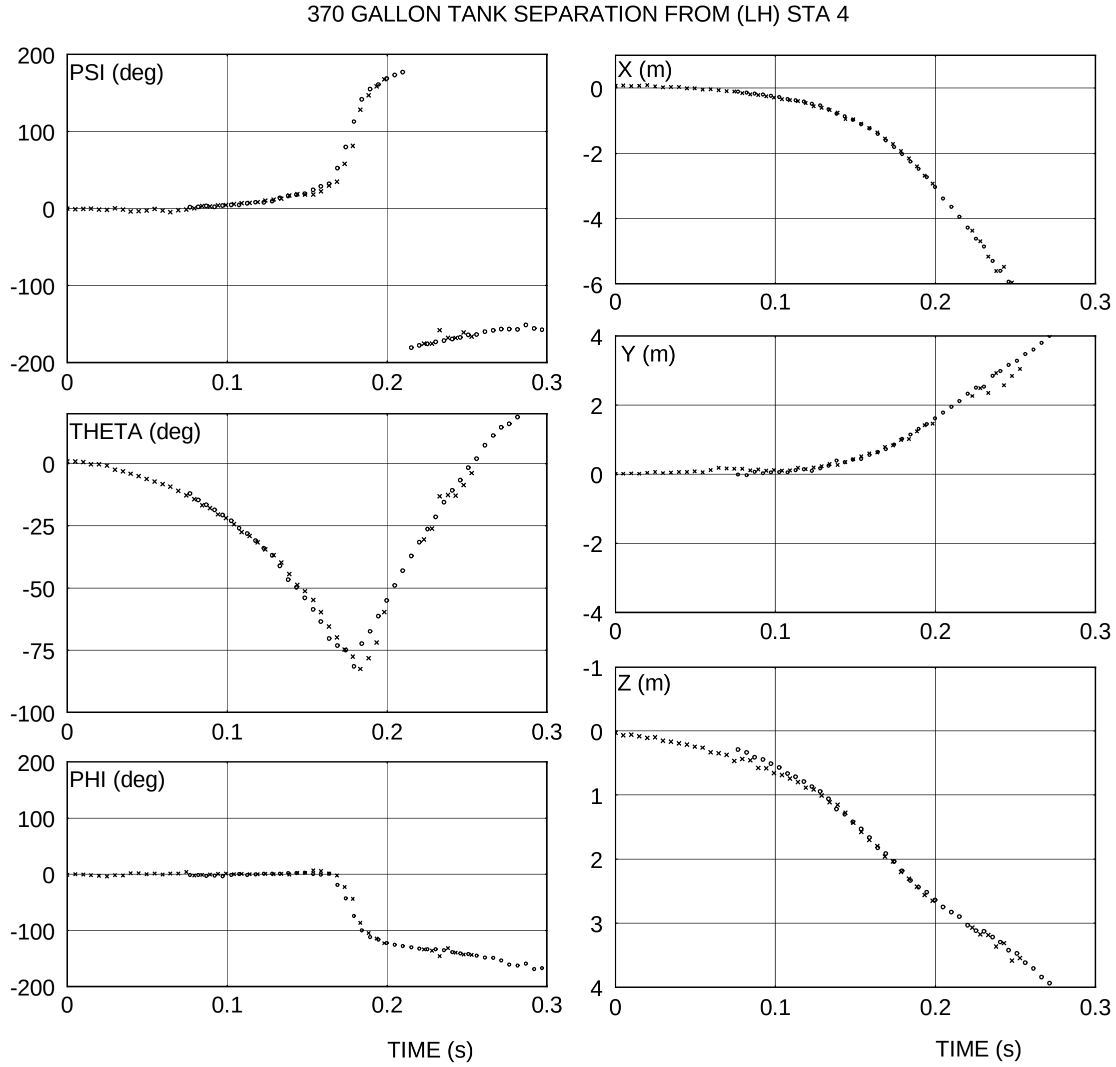


Fig. 21 Tank attitude and position time-histories (see Fig. 20).
RNLAF Flight N3, Results of both cameras combined.

Fig. 22 Flight N1: post-flight picture of ventral fin.

Fig. 23 Flight N2: post-flight picture of ventral fin.

Fig. 24 Flight N3: ventral fin just after tank contact (t = 0.200 s).

Fig. 25 Flight N3: post-flight picture of (old model) ventral fin; also most skin of fin is gone. Also tail hook came down during tank release.

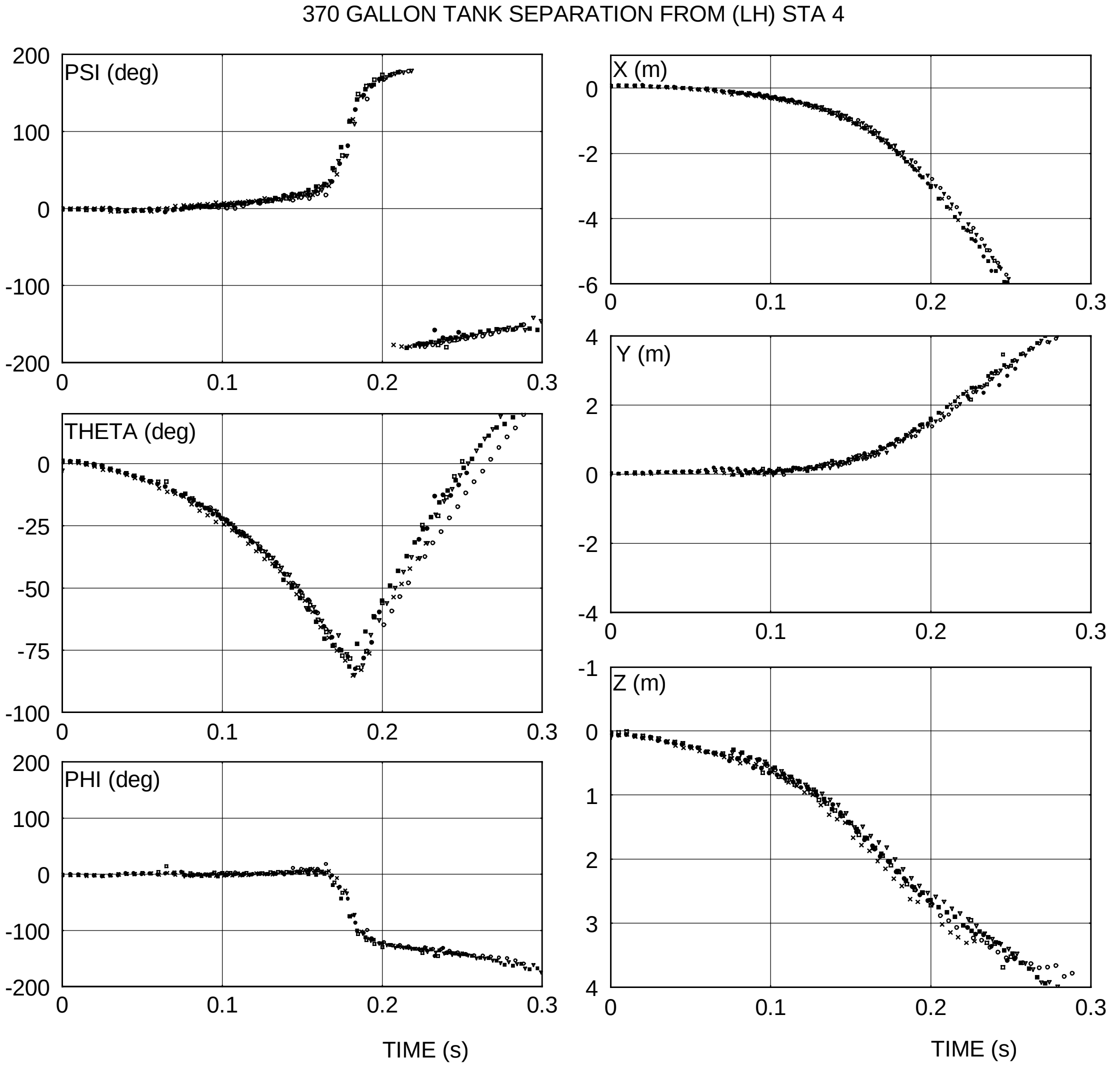


Fig. 26 Tank separation attitude and position time histories combined for three flights: Two results (cameras) per flight.

Fig. 27 370 gallon pylon tank mounted at wing station 4.
Remark the rim (with bolts) at lower-left of cylindrical part of tank body.

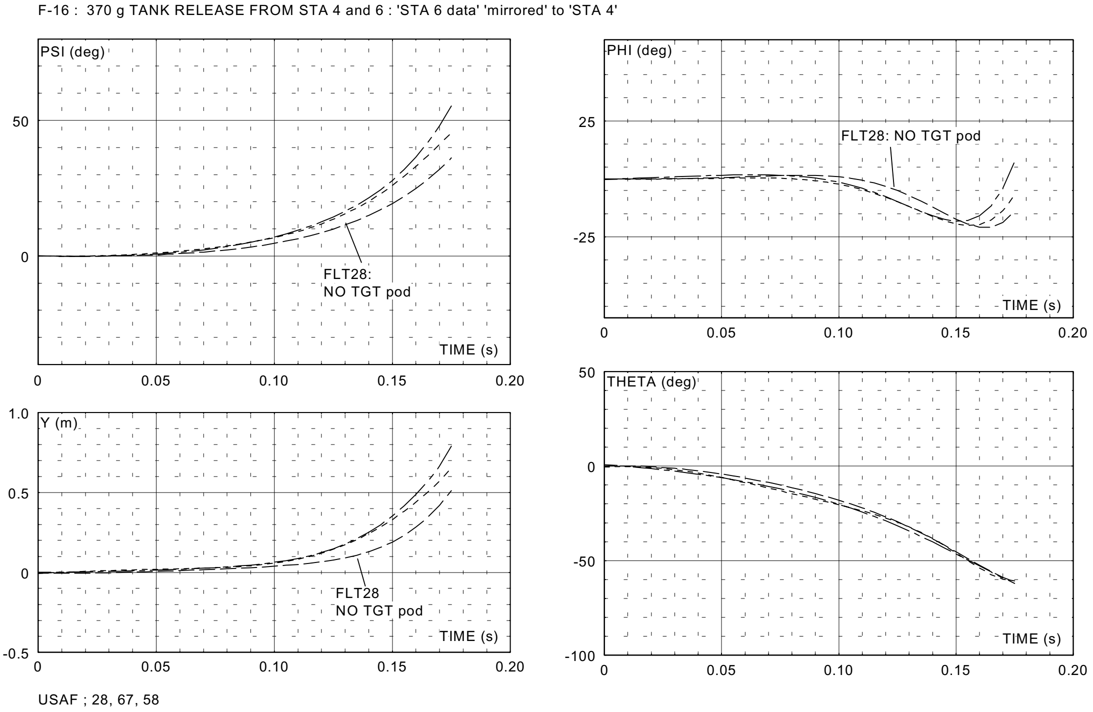


Fig. 28 Comparing USAF test results of three flights: tank from RH sta 6, but “MIRRORED”.
USAF Flights FLT28, FLT67 and FLT54 (16PR10840).
GBU-10 at (standard pylon) sta 3/7; ALQ-131 at CL sta 5; TGT pod at inlet sta 5R.
M=0.90 / 550 KCAS, Az= 1.0 g, AOA = ? deg. FLT28 : NO TGT pod.
FLT67 : with RH TGT pod
FLT54 : with RH TGT pod + LH NAV pod

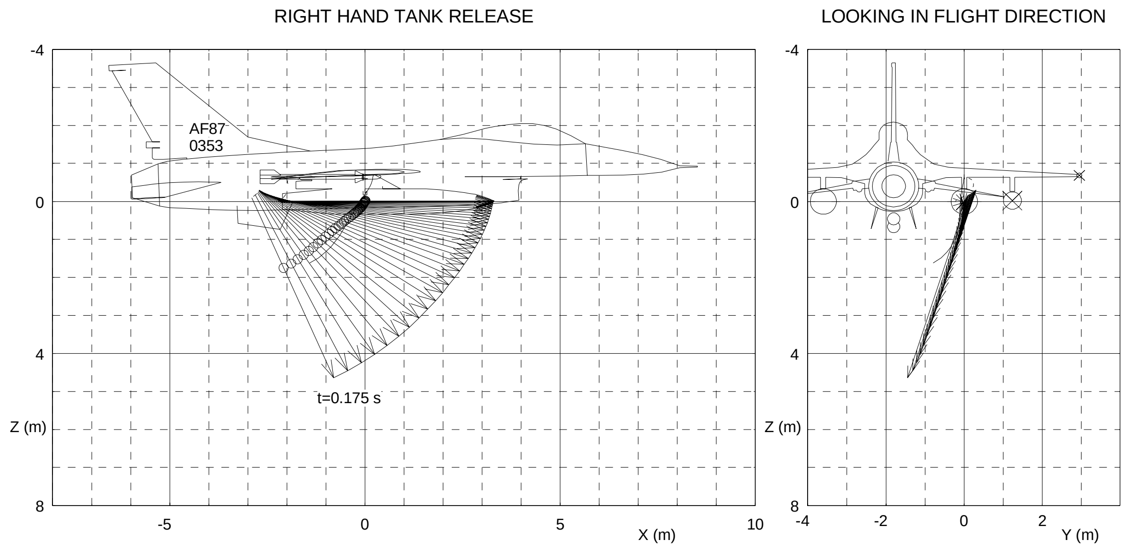


Fig. 29 Tank separation from sta 6; GBU-10C/B at sta 7
FLT28 of F-16 1C4; M = 0.90 / 553 KCAS; Altitude 4188 ft
NO Pods at sta 5R or sta 5L

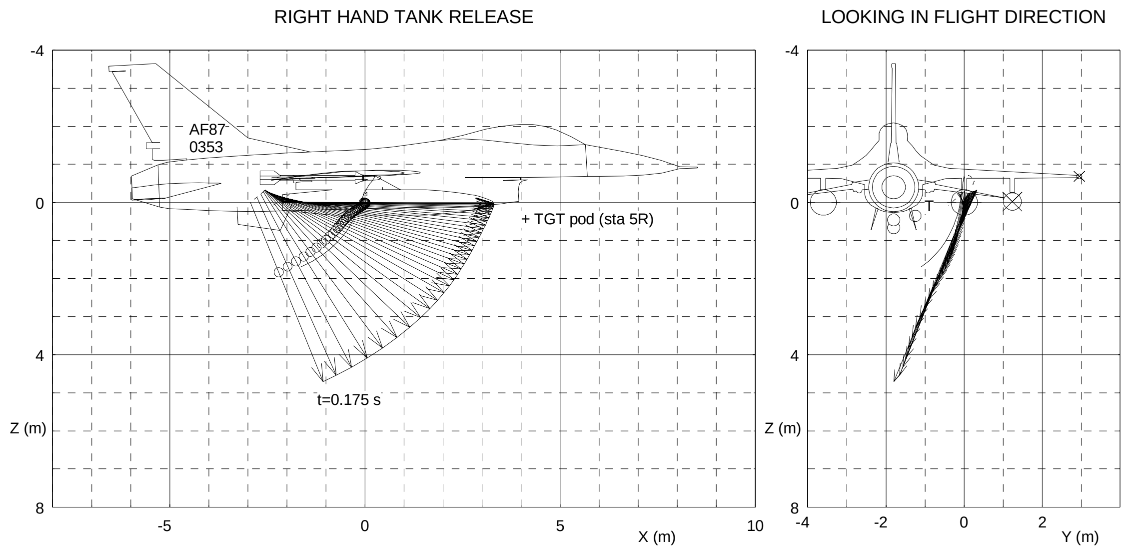


Fig. 30 Tank separation from sta 6; GBU-10C/B at sta 7
FLT67 of F-16 1C4; M = 0.90 / 550 KCAS; Altitude 5380 ft
TGT Pod at sta 5R

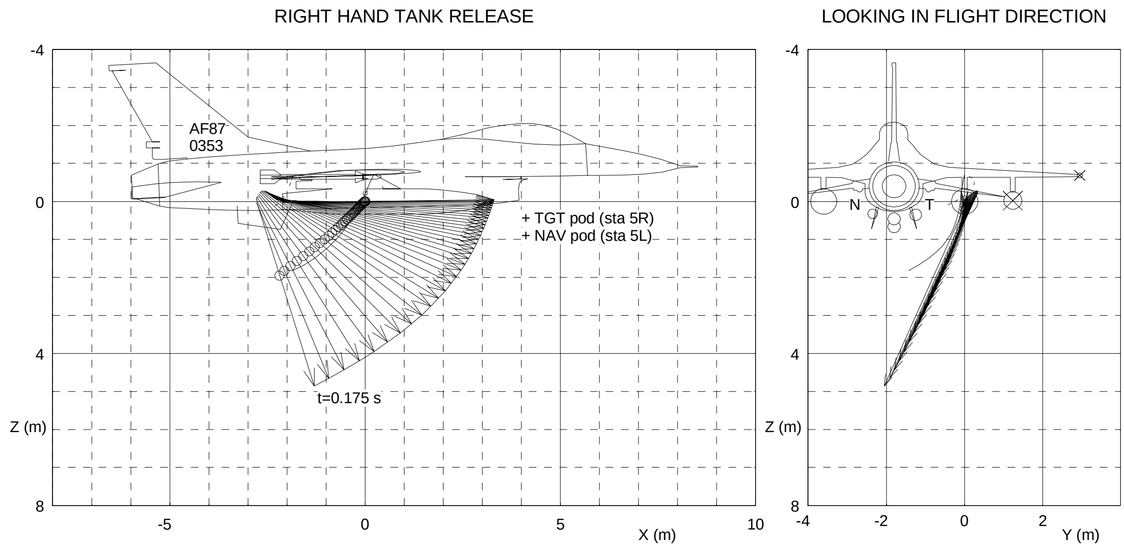


Fig. 31 Tank separation from sta 6; GBU-10C/B at sta 7
FLT54 of F-16 1C4; M = 0.90/ 550 KCAS; Altitude 5070 ft
TGT Pod at sta 5R; NAV pod at sta 5L

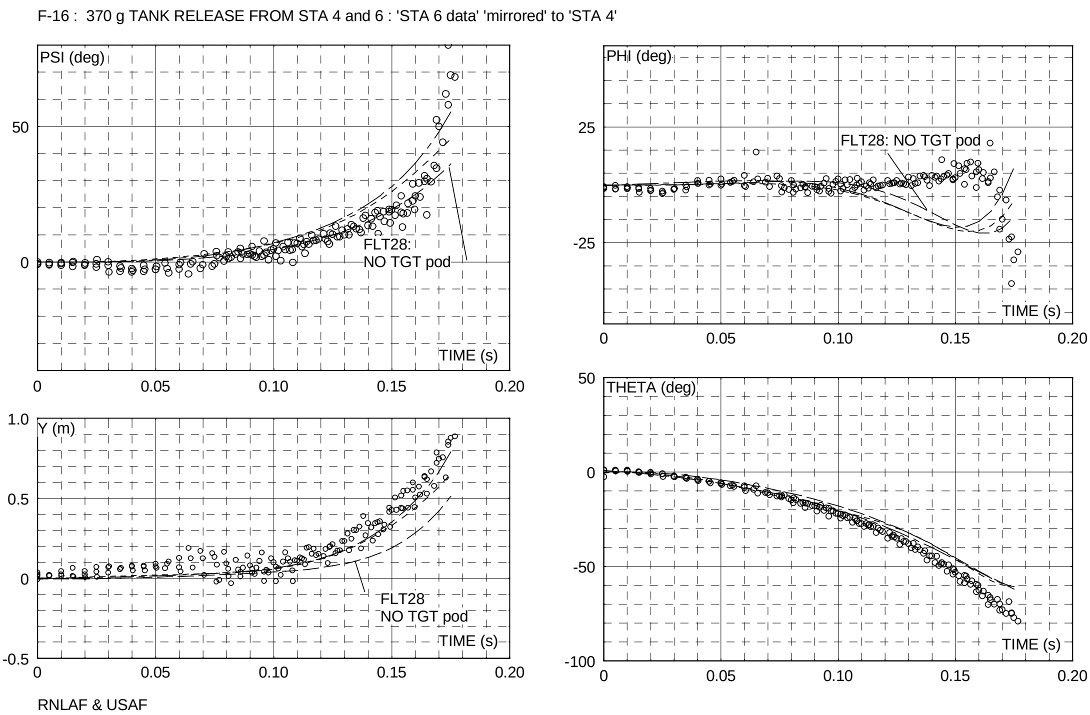


Fig. 32 Comparing (3) USAF and (3) RNLAF tank releases
(USAF tanks from RH sta 6, but "MIRRORED")
GBU-10 at (standard pylon) sta 3/7; ALQ-131 at CL sta 5.
All: M=0.9/ 550 KCAS, Az = 1.0 g; RNLAF AOA 1.8 or 1.9 deg , USAF ? deg.

Biography of authors

Major Tjebbe “Speedy” Haringa heads the F-16 flight test group(also known as Speedy’s Flight Test Center”) at Leeuwarden Air Force Base.
He received his pilot training in Canada in 1977 and accumulated the majority of his 3400 flying hours on the Canadair (Northrop) NF-5 (375) and the F-16 (2600). From 1990 to 1994 he was flight commander of the 323 Tactical Training, Evaluation and Standardisation Squadron, in charge of F-16 flight training, standardisation and flying instructor training.
Maj. Haringa received his test pilot training in 1995 at the Empire Test Pilot School at Boscomb Down, UK. He leaded the selection of nav/tgt pods for the F-16MLU aircraft and leaded integration and qualification tests of various stores and avionics systems. He is currectly the RNLAF seniour F-16 test pilot and is in charge of the integration of nav/tgt pods and the assessment of potential candidates for the replacement of the F-16 aircraft.

Jos J. Meijer is Senior Research Scientist at Nationaal Lucht-en Ruimtevaartlaboratorium
National Aerospace Laboratory, NLR, in Amsterdam, The Netherlands.
Jos Meijer received an “Ingenieur” degree (M.S. equivalent) in Aeronautical Engineering from Delft Technological University in 1968. Upon graduation he performed two years of postgraduate studies on structural and aeroelastic subjects. In 1970 he joined the Department of Unsteady Aerodynamics and Aeroelasticity and since 1999 the Department of Computational Aerodynamics and Aeroelasticity at the National Aerospace Laboratory.
He has been involved in the flutter clearance of fighter type aircraft, since 1984 as a project leader. He was also involved in dynamic response studies during store releases and a F-16 ride quality study (carried out under contract for Lockheed Martin Aeronautics Company) where he was responsible for the aeroelastic modeling and calculations. Next he participated in a flutter study of a wind tunnel model of a supercritical transport type wing and in the aeroelastic modeling of rotary wing systems, applied to wind energy converters. From 1985, he is responsible for the flutter clearance of new F-16 configurations and the development of new techniques to investigate aeroelastic matters of both civil and fighter-type aircraft. Since 1989, he participates as a project leader in a study of transonic limit cycle oscillations of fighter aircraft (partly under contract for LMAC). Recently, he is also involved, as a project leader, in the development of a numerical simulation method for the aeroelastic behavior of fighter type aircraft, in particular, non-linear flutter in the transonic speed regime.
Professional society: Member AIAA and member RioE (NL).

Kees R.Rijzebol (in English: **Case** Ryzebol) was born in 1941 in Warffum, in the Netherlands. After completing his military service in the Royal Netherlands Air Force he started and finished his study at the Technical University of Delft as a M.Sc. in Aerospace Engineering.
Since 1970 he is an employee of the National Aerospace Laboratory NLR at Amsterdam. From the beginning he was and still is involved in analysis and flight test programs for the Royal Netherlands Air Force (RNLAF or KLu), Royal Netherlands Navy Air Force (MLD), Fokker Aircraft and a few foreign air forces. Aircraft-store compatibility was analyzed and, most of all: store separation prediction, flight testing and analyses were performed for F-104G, (N)F-5A, CF-5A, F-16A, Fokker Maritime / Enforcer, Lockheed P-2H Neptune, Breguet Atlantic and Westland Lynx. As a flight test engineer / in-flight observer he was actively involved in separation tests.
He was also involved in flight test programs with civil aircraft (in civil or military programs) in which he was usually responsible for planning of the flight test programs and for in-flight test management.
In recent years he was involved in a number of contacts and contract negotiations for and activities in programs of foreign air forces and industries concerning requirements of the Royal Netherlands Air Force or foreign air forces.
Kees Rijzebol holds a private pilot license from 1969 and is maintaining his piloting proficiency.