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Flight Dynamic Simulation of Fighter In the Asymmetric External Store Release Process

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Abstract. In the fighter design, it is important to evaluate and analyze the flight dynamic of the aircraft earlier in the development process. One of the case is the dynamics of external store release process. A simulation tool can be used to analyze the fighter/external store system's dynamics in the preliminary design stage. This paper reports the flight dynamics of Jet Fighter Experiment (JF-1 E) in asymmetric Advance Medium Range Air to Air Missile (AMRAAM) release process through simulations. The JF-1 E and AIM 120 AMRAAAM models are built by using Advanced Aircraft Analysis (AAA) and Missile Datcom software. By using these softwares, the aerodynamic stability and control derivatives can be obtained and used to model the dynamic characteristic of the fighter and the external store. The dynamic system is modeled by using MATLAB/Simulink software. By using this software, both the fighter/external store integration and the external store release process is simulated, and the dynamic of the system can be analyzed.

Keywords : fighter, external store, flight dynamic simulation

1. Introduction

Generally, a fighter is designed to paralyze the enemies. For this purpose, a fighter usually equipped with weapons or external stores such as missiles, bombs, rockets, etc. In case of external store release to attack enemies, a fighter undergoes a huge disturbance due to the loss of components with a large mass and a considerable aerodynamics contribution. If left unchecked, this process could interfere the fighter's combat operation. Therefore, the dynamics of a fighter in the external store release process is a case that needs to be analyzed and evaluated in the beginning of the development process of the fighter.

One of the method that can be used to perform the analysis is simulation. Simulation has several advantages compared with flight test method. By using this method, it spent only 40% of the fund compared with the flight test method. It is safer to use simulation due to zero percent accident risk. It also prevent losses due to aircraft damage. Simulation is also a flexibel method as it can be done under various conditions [1].

One of the tool that can be used in simulation is Computational Fluid Dynamics (CFD). CFD can be used to do a lot of simulation and analysis. By using CFD, the static stability derivatives can be computed and then the stability of the aircraft can be modelled and predicted [2]. It can be used to simulate and analyze the separation characteristics of a missile, either using Cartesian grids [3] or using Grid-Free Euler Solver [4].

Another tool that can be used in the dynamics simulation and analysis is MATLAB/Simulink software. Compared to CFD, the numerical calculation of MATLAB/Simulink is lighter on computer and takes a relatively short time.

Institut Teknologi Bandung (ITB), that has been involved in the development process of IF-X, a fighter that will be produced by Indonesian government in cooperation with South Korea Government, is developing a simulation model and facility for a fighter. The fighter model being developed is named Jet-Fighter Experiment (JF-1 E) [1][5]. In the previous works [1][5], besides modeling of JF-1E, air combat maneuvers simulation has also been done. In the next development, it is important to analyze the dynamic response of the fighter for various external store release scenarios. Therefore, a dynamic system that consist of fighter and external store model is needed to be developed.

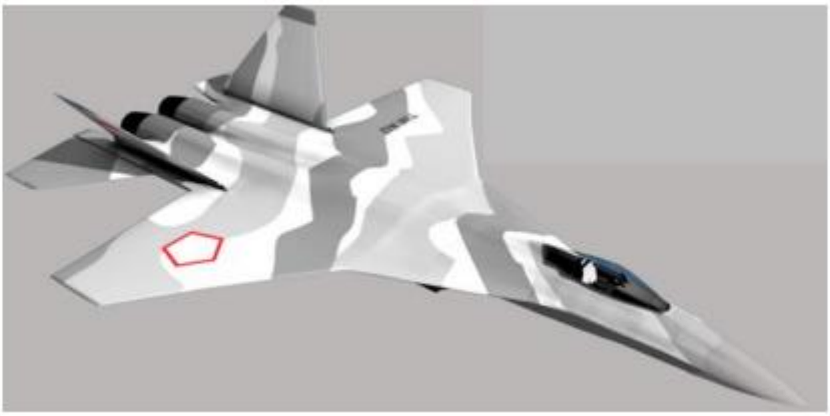


Figure 1. The illustration of JF-1 E model [1]

The present paper will specifically discuss the simulation of JF-1 E's dynamics in the asymmetric external storage release process using MATLAB/Simulink software.

2. Method

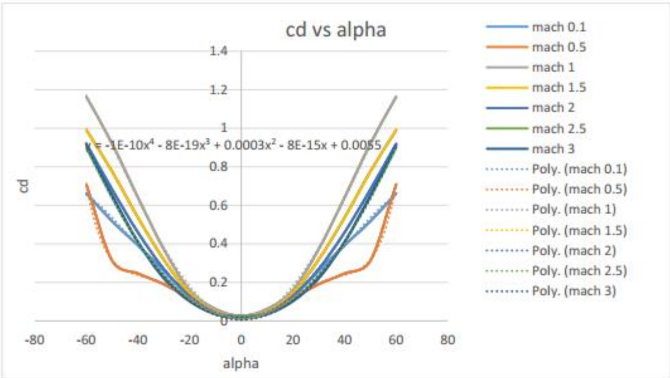
The modeling of JF-1 E has been done by using Advanced Aircraft Analysis (AAA) software, so the stability and control derivatives of its aircraft has been obtained, both in longitudinal [1] and lateral-directional [5] dimension. By using Missile Datcom software, the stability derivatives of AIM 120 AMRAAM has been obtained, too [6]. Both AAA and Missile Datcom are suitable softwares for calculating aerodynamic parameters of an aircraft and a missile at the preliminary design stage. Table 1 shows the stability and control derivatives of JF-1 E as the result of the previous works [1][5] :

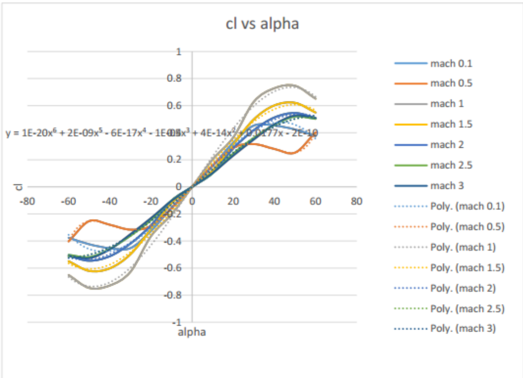
Table 1. JF-1 E stability derivatives

Parameters		h = 3000 m		
		V = 240 m/s	**V = 300 m/s**	**V = 400 m/s**
C_X	C_{X_0}	-0,0149	-0,0149	-0,0149
	C_{X_α} (/rad)	0,1658	0,123	0,1454
	$C_{X_{\alpha^2}}$ (/rad)	0,0055	0,0055	0,0055
	C_{X_M}	0,0027	0,003	0,0035
	$C_{X_{\delta_F}}$ (/rad)	0	0	0
	$C_{X_{iH}}$ (/rad)	0,0033	-0,0038	0
C_Y	C_{Y_β} (/rad)	-0,6685	-0,6685	-0,6685
	C_{Y_0}	0	0	0

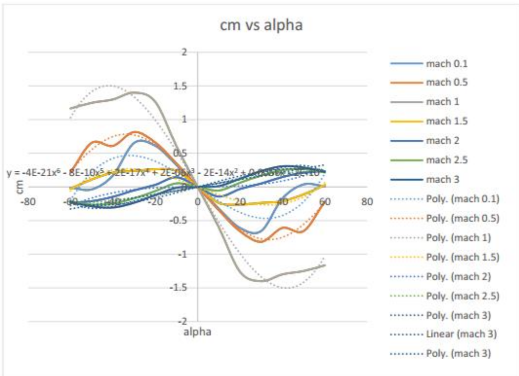
	C_{Y_r} (/rad)	0,5952	0,5894	0,5786
	$C_{Y_{\delta_r}}$ (/rad)	0,1281	0,0829	0,0049
	$C_{Y_{\delta_a}}$ (/rad)	0	0	0
$\boldsymbol{C_Z}$	C_{Z_α} (/rad)	3,0401	3,5298	3,7369
	C_{Z_0}	0,1078	0,1059	-0,0548
	C_{Z_q} (/rad)	5,7818	5,5973	5,8977
	$C_{Z_{\alpha^2}}$ (/rad)	-0,0027	-0,0027	-0,0027
	$C_{Z_{\delta_f}}$ (/rad)	0	0	0
	$C_{Z_{iH}}$ (/rad)	-0,2506	-0,1128	-0,0619
$\boldsymbol{C_l}$	C_{l_0}	0	0	0
	C_{l_β} (/rad)	-0,0891	-0,0894	-0,0895
	C_{l_p} (/rad)	-0,2588	-0,222	-0,2231
	$C_{l_{\delta_r}}$ (/rad)	0,015	0,0097	0,0006
	$C_{l_{\delta_a}}$ (/rad)	0,1112	0,1158	0,422
$\boldsymbol{C_m}$	C_{m_0}	-0,049	-0,0497	-0,0619
	C_{m_α} (/rad)	-0,9263	-1,1154	-1,144
	C_{m_T}	0,0039	0,0044	0,0037
	C_{m_q} (/rad)	-4,6024	-4,0754	-4,3082
	$C_{m_{\delta_f}}$ (/rad)	0	0	0
	$C_{m_{iH}}$ (/rad)	0,3347	0,1501	0,0086
$\boldsymbol{C_n}$	C_{n_0}	0	0	0
	C_{n_β} (/rad)	0,2371	0,2329	0,2269
	C_{n_r} (/rad)	-0,3722	-0,3592	-0,3471
	$C_{n_{\delta_r}}$ (/rad)	-0,0843	-0,0546	-0,0032
	$C_{n_{\delta_a}}$ (/rad)	-0,0032	-0,003	0,0006

One of the weapon or external store of JF-1 E is a missile named AIM 120 AMRAAAM. It is a flexible missile that can be used in either air-to-air or ground-to-air scenario [6]. Figure 2 shows the stability derivatives of AIM 120 AMRAAM as the result of the previous works [6] :





(a) (b)



(c)

Figure 2. (a) C_d vs alpha graph, (c) C_l vs alpha graph, C_m vs alpha graph, of AIM 120 AMRAAM model

The works to build the dynamic system can be classified into several parts :

a. modeling JF-1 E's airframe and control coefficients ;
b. modeling AIM 120 AMRAAAM coefficients ;
c. modeling aerodynamic forces and moments of JF-1 E and AMRAAM ;
d. modeling the transients equations of external store release process ;
e. modeling the equations of motion.

The general schematic diagram of the flight dynamic simulation of JF-1 E in the asymmetric AIM 120 AMRAAM external store release process is represented in Figure 3.

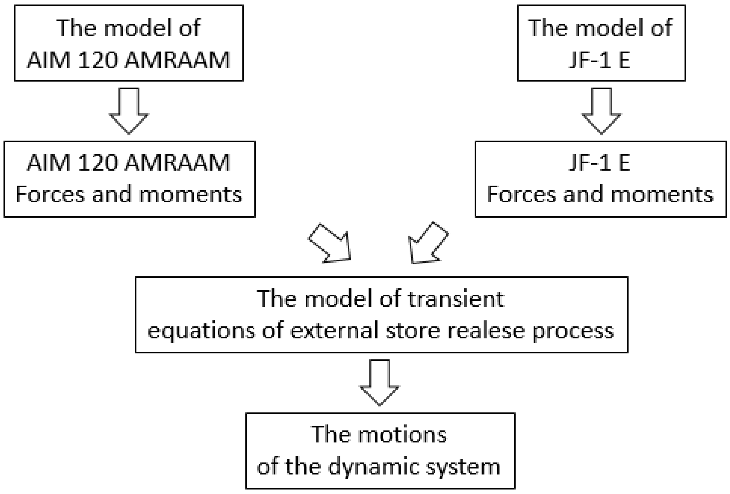


Figure 3. Schematic diagram of the simulation

The model of JF-1 E is built to obtain its airframe and control coefficients. By using all of the stability derivatives that has been obtained from AAA, the fighter's airframe and control calculation blocks was made in Simulink. The total aerodynamic coefficients of the fighter is the sum of the airframe and the control coefficients.

The model of AIM 120 AMRAAM is built to obtain only its airframe coefficients. The airframe coefficients calculation block in Simulink can be made by using stability derivatives that has been obtained by using Missile Datcom software.

Both JF-1 E and AIM 120 AMRAAM coefficients are used to obtain their aerodynamic forces and moments. Since the stability derivatives of JF-1 E and AIM 120 AMRAAM have different references, it will be easier to combine their forces and moments.

To model the fighter/external stores integration and the external store release process, some equations are needed to be developed, called the transients equation of external store release process. The equations must satisfy all of the changed properties of the fighter/external store system caused by the attached or released external stores. The attached or released external stores can change the total mass, total inertia, center of gravity (CG) location, total forces, and total moments of the system. But the effect of the changes of those properties to the equations of motion of the aircraft can be ignored, since the equation of motion are derived relative to the CG.

Generally, the total magnitude of the fighter/external store system's properties is the superposition of the fighter's and the external store's properties. For example, the total mass of the system is the sum of the fighter's mass and the attached external stores's mass. To represent either the integration or the release process, it is needed to add an additional constant to the equation. This constant's magnitude will change over time depending on each external store condition. If the external store is attached to the fighter's body or wing, this constant's magnitude is one. But, if the external store is released, this constant's magnitude will be zero. This additional constant is similar with the binary digit (bit) in the computer. Bit only has two possible values, it is always one or zero.

The transients equation below is used to model the external store release process. For these equations, it is assumed that four AIM 120 AMRAAMs are attached on the wing of JF-1 E. It is also assumed that the aerodynamic forces acting to JF-1 E's airframe is always distributed in a balance condition between the left and the right side, so the total aerodynamic force always located in the middle. Here it is the detailed equations

$$m_{Total} = m_{Aircraft} + m_{Missile}\,(C_1 + C_2 + C_3 + C_4) \tag{1}$$

$$X_{CG_{Total}} = \frac{X_{CG_{Aircraft}} m_{Aircraft} + m_{Missile}\,(X_1C_1 + X_2C_2 + X_3C_3 + X_4C_4)}{m_{Aircraft} + m_{Missile}(C_1 + C_2 + C_3 + C_4)} \tag{2}$$

$$Y_{CG_{Total}} = \frac{Y_{CG_{Aircraft}} m_{Aircraft} + m_{Missile}\,(Y_1C_1 + Y_2C_2 + Y_3C_3 + Y_4C_4)}{m_{Aircraft} + m_{Missile}\,(C_1 + C_2 + C_3 + C_4)} \tag{3}$$

$$Z_{CG_{Total}} = \frac{Z_{CG_{Aircraft}} m_{Aircraft} + m_{Missile}(Z_1C_1 + Z_2C_2 + Z_3C_3 + Z_4C_4)}{m_{Aircraft} + m_{Missile}(C_1 + C_2 + C_3 + C_4)} \tag{4}$$

$$\begin{aligned} I_{xx_{Total}} = I_{xx_{Aircraft}} &+ \left(\left(Y_{CG_{Total}} - Y_{CG_0}\right)^2 + \left(Z_{CG_{Total}} - Z_{CG_0}\right)^2\right) m_{Aircraft} + C_1(I_{xx_{Missile}} \\ &+ \left(\left(Y_1 - Y_{CG_{Total}}\right)^2 + \left(Z_1 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) + C_2(I_{xx_{Missile}} \\ &+ \left(\left(Y_2 - Y_{CG_{Total}}\right)^2 + \left(Z_2 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) + C_3(I_{xx_{Missile}} \\ &+ \left(\left(Y_3 - Y_{CG_{Total}}\right)^2 + \left(Z_3 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) + C_4(I_{xx_{Missile}} \\ &+ \left(\left(Y_4 - Y_{CG_{Total}}\right)^2 + \left(Z_4 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) \end{aligned} \tag{5}$$

$$\begin{aligned} I_{yy_{Total}} = I_{Aircraft} &+ \left(\left(X_{CG_{Total}} - X_{CG_0}\right)^2 + \left(Z_{CG_{Total}} - Z_{CG_0}\right)^2\right) m_{Aircraft} + C_1(I_{yy_{Missile}} \\ &+ \left(\left(X_1 - X_{CG_{Total}}\right)^2 + \left(Z_1 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) + C_2(I_{yy_{Missile}} \\ &+ \left(\left(X_2 - X_{CG_{Total}}\right)^2 + \left(Z_2 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) + C_3(I_{yy_{Missile}} \\ &+ \left(\left(X_3 - X_{CG_{Total}}\right)^2 + \left(Z_3 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) + C_4(I_{yy_{Missile}} \\ &+ \left(\left(X_4 - X_{CG_{Total}}\right)^2 + \left(Z_4 - Z_{CG_{Total}}\right)^2\right) m_{Missile}) \end{aligned} \tag{6}$$

$$\begin{aligned} I_{zz_{Total}} = I_{zz_{Aircraft}} &+ \left(\left(X_{CG_{Total}} - X_{CG_0}\right)^2 + \left(Y_{CG_{Total}} - Y_{CG_0}\right)^2\right) m_{Aircraft} + C_1(I_{zz_{Missile}} \\ &+ \left(\left(Y_1 - Y_{CG_{Total}}\right)^2 + \left(X_1 - X_{CG_{Total}}\right)^2\right) m_{Missile}) + C_2(I_{zz_{Missile}} \\ &+ \left(\left(Y_2 - Y_{CG_{Total}}\right)^2 + \left(X_2 - X_{CG_{Total}}\right)^2\right) m_{Missile}) + C_3(I_{zz_{Missile}} \\ &+ \left(\left(Y_3 - Y_{CG_{Total}}\right)^2 + \left(X_3 - X_{CG_{Total}}\right)^2\right) m_{Missile}) + C_4(I_{zz_{Missile}} \\ &+ \left(\left(Y_4 - Y_{CG_{Total}}\right)^2 + \left(X_4 - X_{CG_{Total}}\right)^2\right) m_{Missile}) \end{aligned} \tag{7}$$

$$\begin{aligned} J_{xy_{Total}} = J_{xy_{Aircraft}} &+ \left(X_{CG_{Total}} - X_{CG_0}\right)\left(Y_{CG_{Total}} - Y_{CG_0}\right) m_{Aircraft} \\ &+ C_1\left(J_{xy_{Missile}} + \left(X_{CG_{Total}} - X_1\right)\left(Y_1 - Y_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_2\left(J_{xy_{Missile}} + \left(X_{CG_{Total}} - X_2\right)\left(Y_2 - Y_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_3\left(J_{xy_{Missile}} + \left(X_{CG_{Total}} - X_3\right)\left(Y_3 - Y_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_4\left(J_{xy_{Missile}} + \left(X_{CG_{Total}} - X_4\right)\left(Y_4 - Y_{CG_{Total}}\right) m_{Missile}\right) \end{aligned} \tag{8}$$

$$\begin{aligned} J_{xz_{Total}} = J_{xz_{Aircraft}} &+ \left(X_{CG_{Total}} - X_{CG_0}\right)\left(Z_{CG_{Total}} - Z_{CG_0}\right) m_{Aircraft} \\ &+ C_1\left(J_{xz_{Missile}} + \left(Y_1 - Y_{CG_{Total}}\right)\left(Z_1 - Z_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_2\left(J_{xz_{Missile}} + \left(Y_2 - Y_{CG_{Total}}\right)\left(Z_2 - Z_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_3\left(J_{xz_{Missile}} + \left(Y_3 - Y_{CG_{Total}}\right)\left(Z_3 - Z_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_4\left(J_{xz_{Missile}} + \left(Y_4 - Y_{CG_{Total}}\right)\left(Z_4 - Z_{CG_{Total}}\right) m_{Missile}\right) \end{aligned} \tag{9}$$

$$\begin{aligned} J_{yz_{Total}} = J_{yz_{Aircraft}} &+ \left(Y_{CG_{Total}} - Y_{CG\,0}\right)\left(Z_{CG_{Total}} - Z_{CG_0}\right) m_{Aircraft} \\ &+ C_1\left(J_{yz_{Missile}} + \left(X_{CG_{Total}} - X_1\right)\left(Z_1 - Z_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_2\left(J_{xz_{Missile}} + \left(X_{CG_{Total}} - X_2\right)\left(Z_2 - Z_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_3\left(J_{xz_{Missile}} + \left(X_{CG_{Total}} - X_2\right)\left(Z_3 - Z_{CG_{Total}}\right) m_{Missile}\right) \\ &+ C_4\left(J_{xz_{Missile}} + \left(X_{CG_{Total}} - X_4\right)\left(Z_4 - Z_{CG_{Total}}\right) m_{Missile}\right) \end{aligned} \quad (10)$$

$$F_{x_{Total}} = F_{x_{Aircraft}} + F_{x_{Missile}}\left(C_1 + C_2 + C_3 + C_4\right) \quad (11)$$

$$F_{y_{Total}} = F_{y_{Aircraft}} + F_{y_{Missile}}\left(C_1 + C_2 + C_3 + C_4\right) \quad (12)$$

$$F_{z_{Total}} = F_{z_{Aircraft}} + F_{z_{Missile}}\left(C_1 + C_2 + C_3 + C_4\right) \quad (13)$$

$$\begin{aligned} L_{Total} = L_{Aircraft} &+ L_{Missile}C_1 + L_{Missile}C_2 + L_{Missile}C_3 + L_{Missile}C_4 \\ &+ F_{z_{Missile}}\left(Y_1 - Y_{CG_{Total}}\right)C_1 + F_{z_{Missile}}\left(Y_2 - Y_{CG_{Total}}\right)C_2 \\ &+ F_{z_{Missile}}\left(Y_3 - Y_{CG_{Total}}\right)C_3 + F_{z_{Missile}}\left(Y_4 - Y_{CG_{Total}}\right)C_4 \\ &- F_{Y_{Missile}}\left(Z_1 - Z_{CG_{Total}}\right)C_1 - F_{Y_{Missile}}\left(Z_2 - Z_{CG_{Total}}\right)C_2 \\ &- F_{Y_{Missile}}\left(Z_3 - Z_{CG_{Total}}\right)C_3 - F_{Y_{Missile}}\left(Z_4 - Z_{CG_{Total}}\right)C_4 \\ &- \left(Y_{CG_{Total}} - Y_{CG_0}\right)F_{Z_{Aircraft}} + \left(Z_{CG_{Total}} - Z_{CG_0}\right)F_{Y_{Aircraft}} \end{aligned} \quad (14)$$

$$\begin{aligned} M_{Total} = M_{Aircraft} &+ M_{Missile}C_1 + M_{Missile}C_2 + M_{Missile}C_3 + M_{Missile}C_4 \\ &+ F_{z_{Missile}}\left(X_1 - X_{CG_{Total}}\right)C_1 + F_{z_{Missile}}\left(X_2 - X_{CG_{Total}}\right)C_2 \\ &+ F_{z_{Missile}}\left(X_3 - X_{CG_{Total}}\right)C_3 + F_{z_{Missile}}\left(X_4 - X_{CG_{Total}}\right)C_4 \\ &+ F_{X_{Missile}}\left(Z_1 - Z_{CG_{Total}}\right)C_1 + F_{X_{Missile}}\left(Z_2 - Z_{CG_{Total}}\right)C_2 \\ &+ F_{X_{Missile}}\left(Z_3 - Z_{CG_{Total}}\right)C_3 + F_{X_{Missile}}\left(Z_4 - Z_{CG_{Total}}\right)C_4 \\ &+ \left(X_{CG_{Total}} - X_{CG_0}\right)F_{Z_{Aircraft}} - \left(Z_{CG_{Total}} - Z_{CG_0}\right)F_{X_{Aircraft}} \\ &- \left(Z_{CG_{Total}} - Z_{CG_0}\right)F_{Propulsion} \end{aligned} \quad (15)$$

$$\begin{aligned} N_{Total} = N_{Aircraft} &+ N_{Missile}C_1 + N_{Missile}C_2 + N_{Missile}C_3 + N_{Missile}C_4 \\ &- F_{X_{Missile}}\left(Y_1 - Y_{CG_{Total}}\right)C_1 - F_{X_{Missile}}\left(Y_2 - Y_{CG_{Total}}\right)C_2 \\ &- F_{X_{Missile}}\left(Y_3 - Y_{CG_{Total}}\right)C_3 - F_{X_{Missile}}\left(Y_4 - Y_{CG_{Total}}\right)C_4 \\ &- F_{Y_{Missile}}\left(X_1 - X_{CG_{Total}}\right)C_1 - F_{Y_{Missile}}\left(X_2 - X_{CG_{Total}}\right)C_2 \\ &- F_{Y_{Missile}}\left(X_3 - X_{CG_{Total}}\right)C_3 - F_{Y_{Missile}}\left(X_4 - X_{CG_{Total}}\right)C_4 \\ &+ \left(Y_{CG_{Total}} - Y_{CG_0}\right)F_{X_{Aircraft}} + \left(Y_{CG_{Total}} - Y_{CG_0}\right)F_{Propulsion} \\ &+ \left(X_{CG_{Total}} - X_{CG_0}\right)F_{Y_{Aircraft}} \end{aligned} \quad (16)$$

where m is mass, X_{CG}, Y_{CG}, and Z_{CG} are CG location, X, Y, and Z are the location of each external store, I_{xx}, I_{yy}, and I_{zz} are moment of inertia, J_{xy}, J_{xz}, and J_{yz} are product of inertia, F_x, F_y, and F_z are forces, L, M, and N are moments, and C is the additional coefficient of each external store.

The dynamic system's motions is modeled using six-degree-of-freedom (6DOF) equation of motion, so both longitudinal and lateral-directional motions of the system can be simulated and analyzed simultaneously.

3. Results and Discussions

Some scenarios are simulated to analyze the dynamic of the fighter in the external store release process. One of the release process of AIM 120 AMRAAM from JF-1 E's wing is simulated in the following conditions :

- four external stores are attached to the fighter, the one placed in the most left side is released ;

- the system is set in the steady symmetric level flight condition at the speed of 200 m/s and the altitude of 3.000 m;
- the time for simulation is 300 seconds, the external store is released in the 25^{th} second;
- the mass of the fighter is assumed to be constant at 24.000 kg during the simulation ;
- the results of the simulation will be shown from 15^{th} second.

It will be easier to analyze the system if it is in a trim condition before the external store is released. Table 3 shows the magnitude of the inputs given to the fighter to make the system in the steady symmetric level flight condition :

Table 2. Input to the dynamic system

Setting angle of horizontal tail (°)	-22,2151
Flaps deflection (°)	0
Aileron deflection (°)	0
Rudder deflection (°)	0
Thrust (N)	51779,2981

Before the model is simulated, the poles of the linearized system can be analyzed to see the characteristic of the system. Table 3 shows the poles of the dynamic system :

Table 3. The dynamic system's poles

Dimension	Poles
Longitudinal	-0.0102 + 0.0666i
	-0.0102 - 0.0666i
	-0.9170 + 4.6902i
	-0.9170 - 4.6902i
Lateral-Directional	-0.2747 + 3.3275i
	-0.2747 - 3.3275i
	-0.0193
	-1.0486

From table 3 above, the poles show that the system is stable, both in longitudinal and lateral-directional dimension. In the longitudinal dimension, the poles show that the dynamic system has short period mode with a high enough natural frequency. Otherwise, the natural frequency of phugoid mode is quite low. In the lateral-directional dimension, the poles show that the dutch roll mode has a high enough natural frequency. The spiral and roll damping mode show a stable behaviour.

Some of the obtained results of the simulation are as follow :

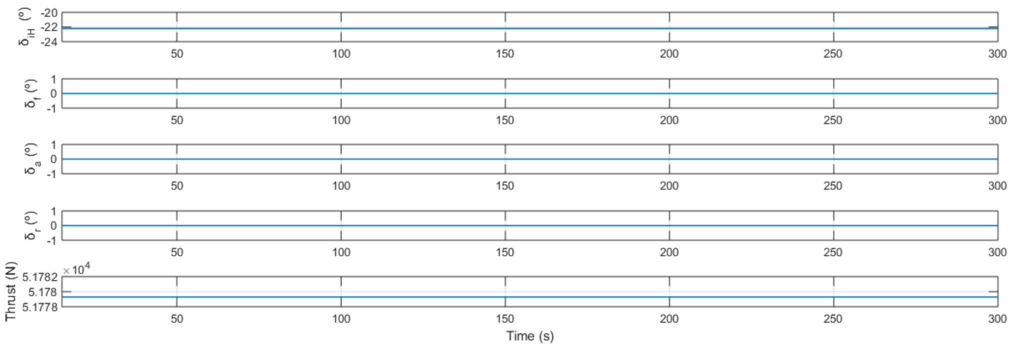


Figure 4. Inputs given to the fighter during the simulation

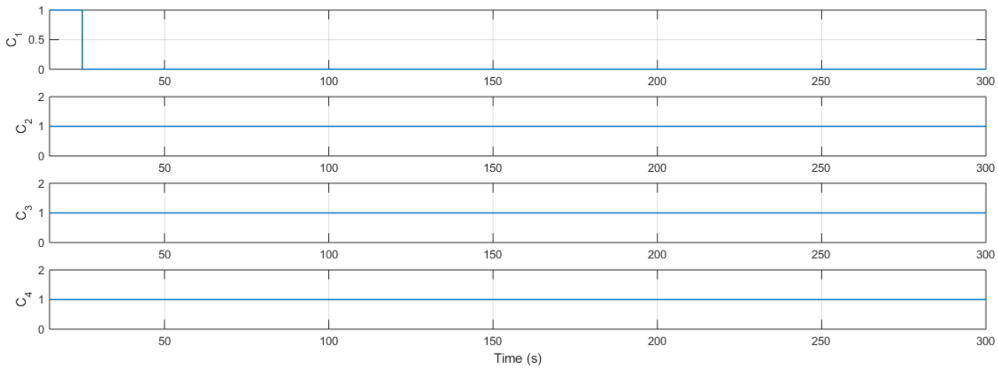


Figure 5. Inputs to the external store release constants

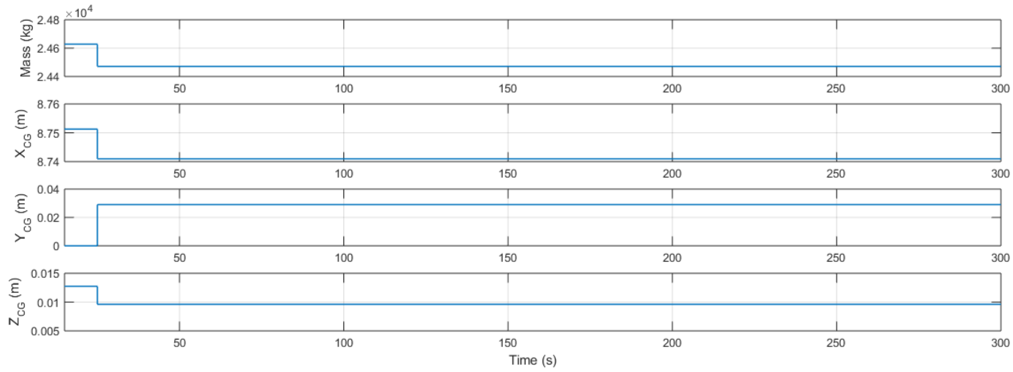


Figure 6. Mass and CG location

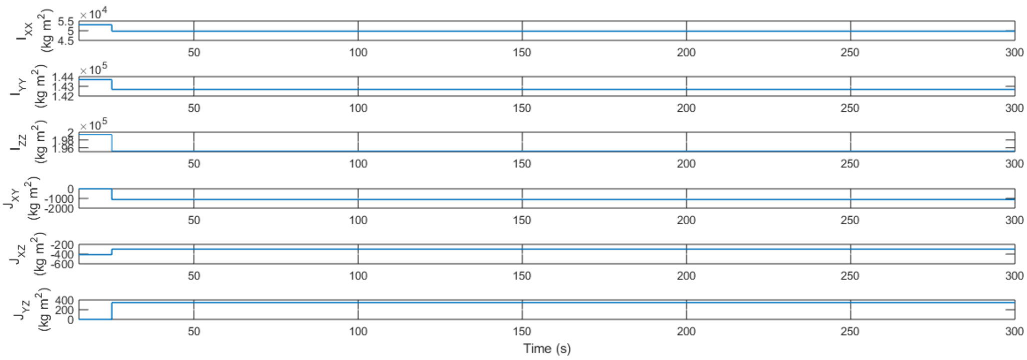


Figure 7. Inertia

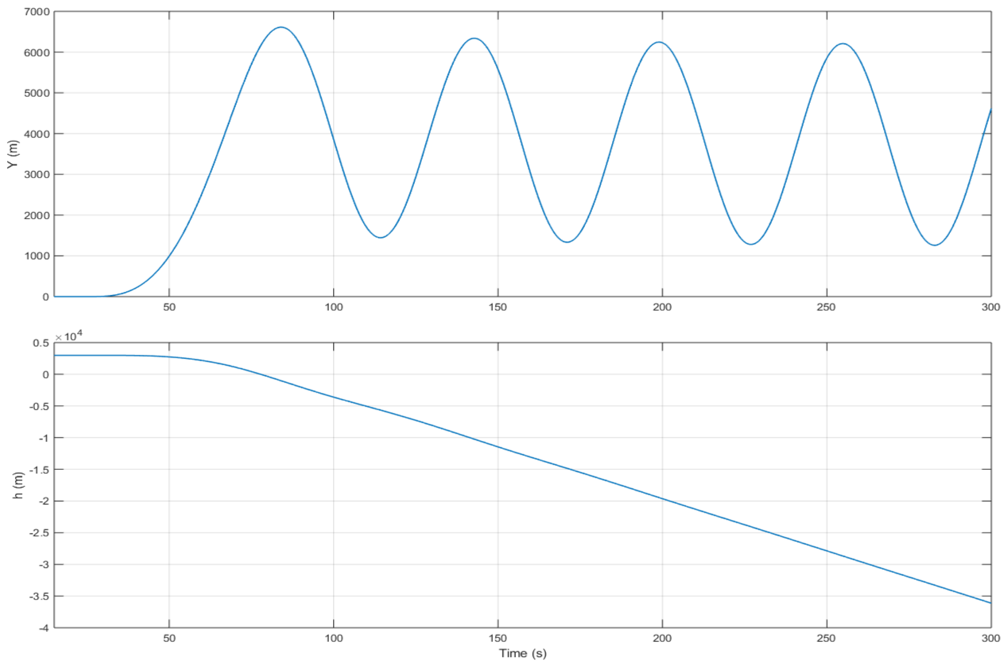


Figure 8. Positions

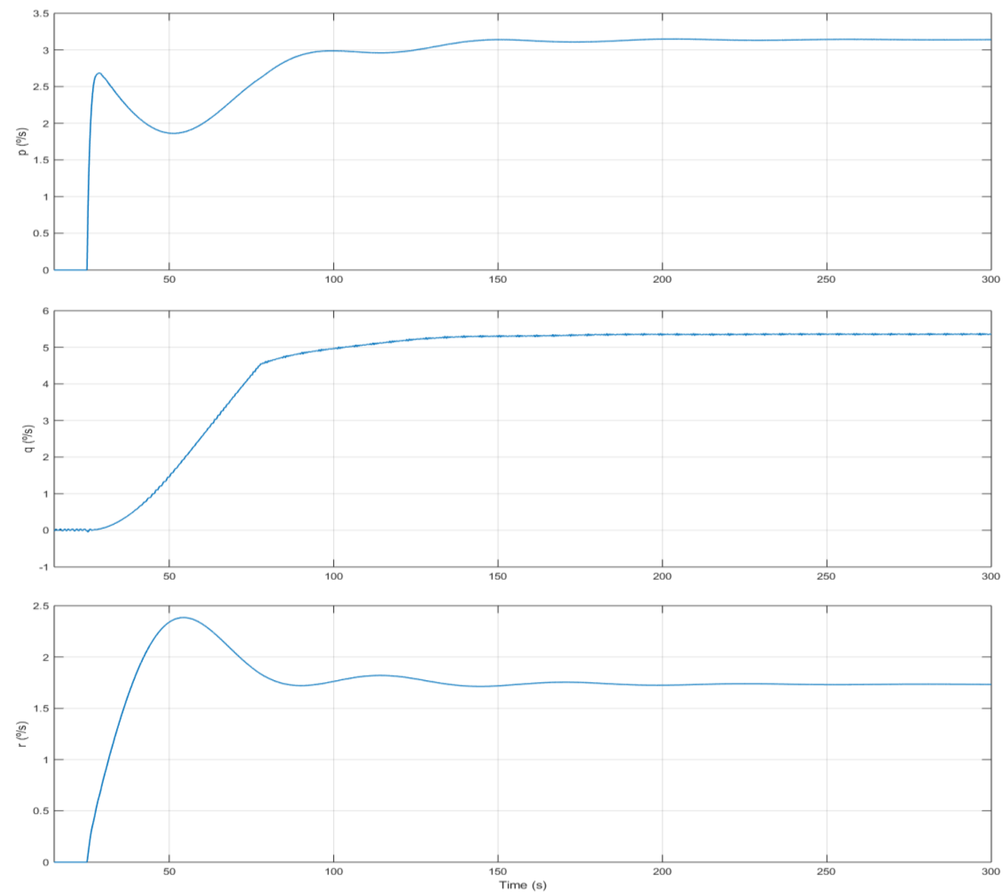


Figure 9. Angular velocity

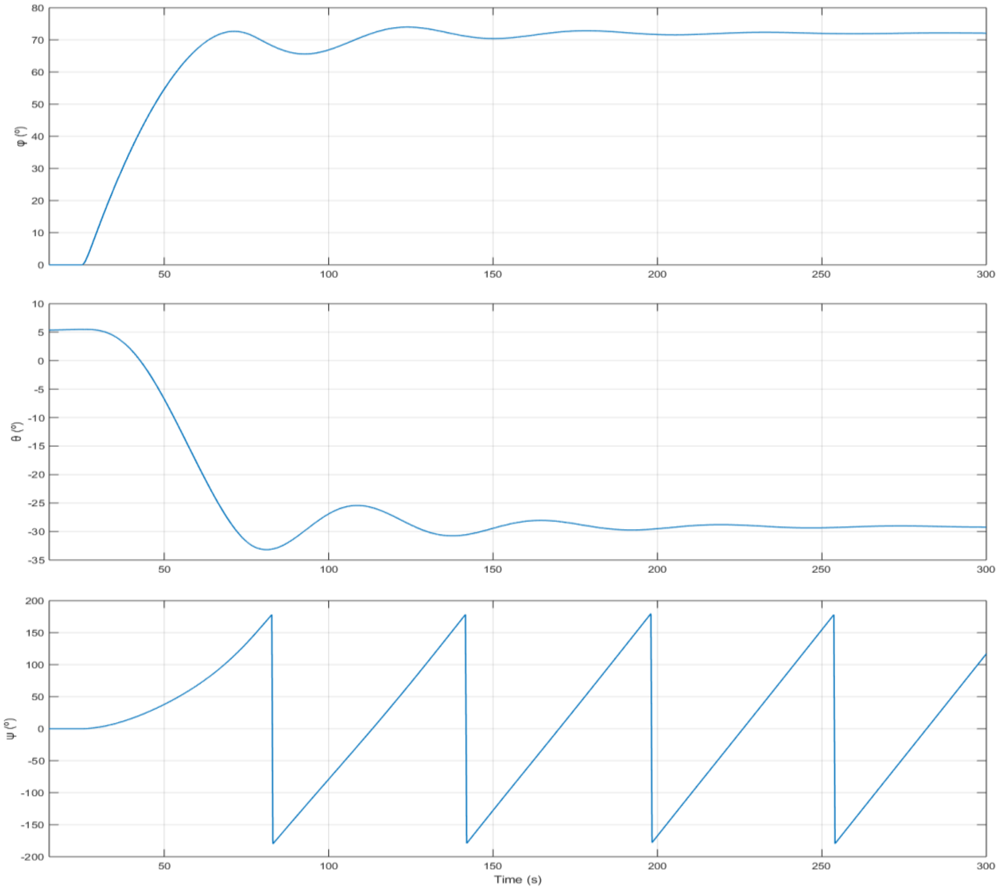


Figure 10. Attitude Angles

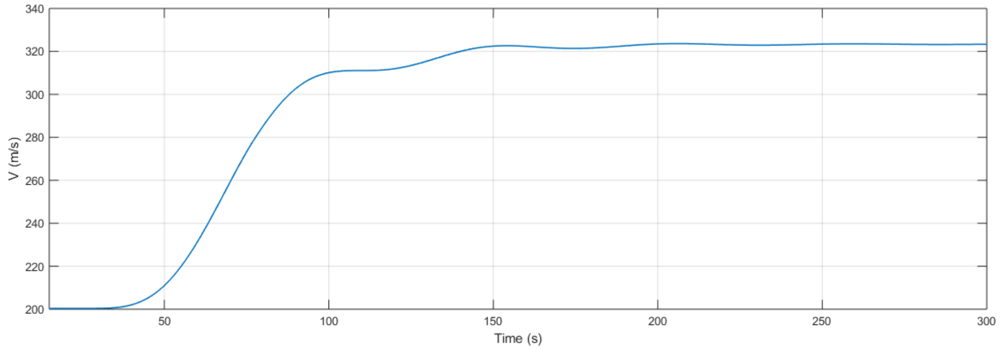


Figure 11. Speed of the dynamic system

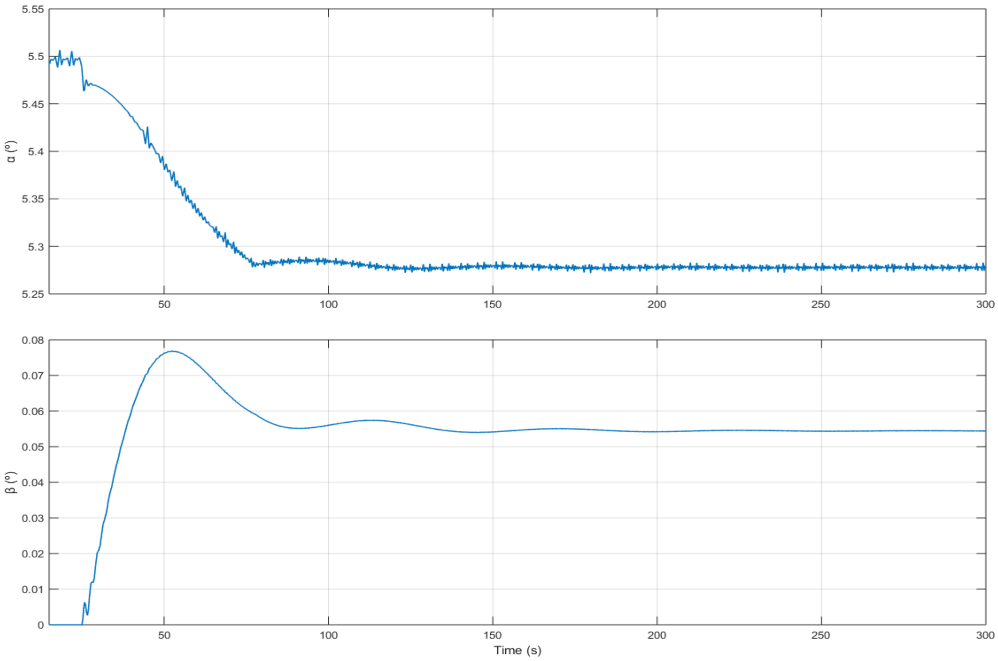


Figure 12. Aerodynamic Angle

According to the simulation results above, it can be seen that the external store release process gives a large enough effect to the dynamics of the fighter. As the external store released, there are some changes in the dynamic system's properties, such as mass, inertia, and center of gravity (CG) location. The total mass of the system is decreased and cause the CG location of the system shift to the right. The mass changes also lead to changes in inertia. All of the changes on these properties will affect the magnitude of the forces and moments of the dynamic system.

The results of the simulation show that the spiral mode of the system is more dominant than the other modes. The system move in a circle to form a spiral while continuing to lose its altitude. The magnitude of the yaw angle show that the system undergoes a turnaround, since it moves from -180° to 180° and back again. The Y-position of the system show a sinusoidal pattern, it indicates that the system move in a circular path with a certain diameter. The dynamic system's speed increases due to the dive. A small side slip angle also arises as the result of spiral motion.

Since the spiral mode has a long enough time constant, it presents no difficulty for the pilot to control the fighter even if it is unstable [7]. To reduce the spiral mode effect, a yaw damper system can be installed to the fighter.

4. Conclusion

The dynamic simulation of JF-1 E in the AIM 120 AMRAAM release process has been done in this paper. The dynamic system model has been built using MATLAB/Simulink and tested. The results of the simulation show that external store release process can affect the dynamic of the fighter. It shows that the spiral mode is more dominant than the other natural responses. Actually, the pilot will find no difficulty to control the fighter since the spiral mode take a long time. To reduce the spiral mode effect, a yaw damper system can be installed to the fighter.

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