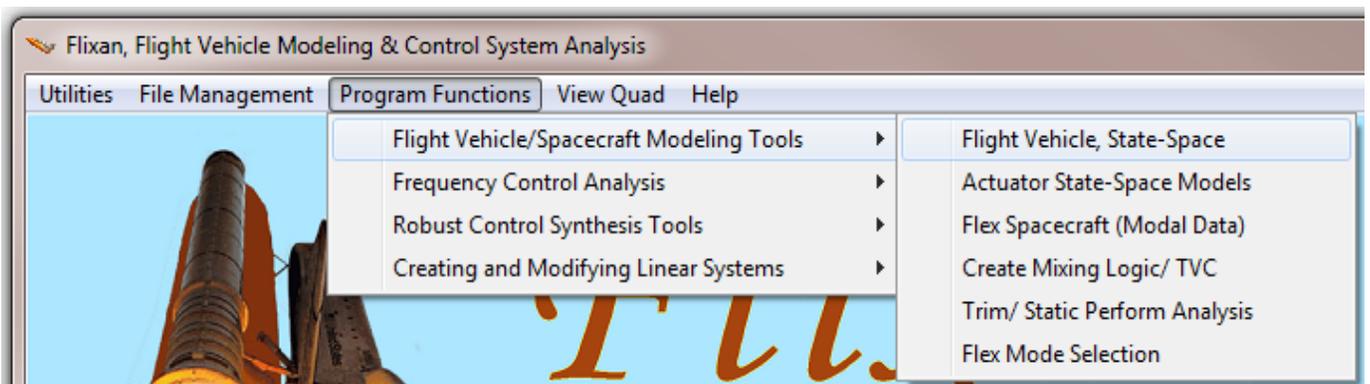
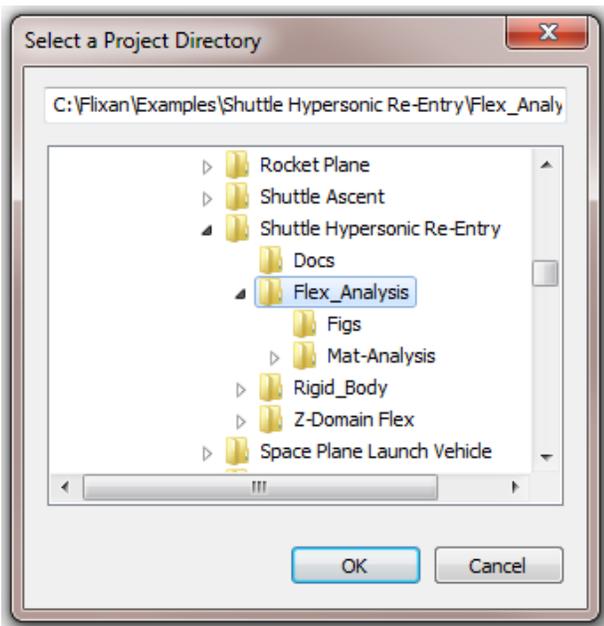


# 3 Flight Vehicle Modeling Program

The Flixan flight vehicle modeling program (FVMP) is used for creating dynamic models of flight vehicles at fixed flight conditions. The models can be rigid or flexible structures, and may include propellant sloshing, tail-wags-dog dynamics, and several other options. It runs either interactively or in batch mode. The user must first select the folder where the vehicle project files are located using the directory selection window. The Flixan main menu comes up, and the program can be selected by clicking on “*Program Functions*”, then “*Flight Vehicle/ Spacecraft Modeling Tools*”, and then “*Flight Vehicle State-Space Models*”, as shown below.



The diagram in Figure (1) shows the files used by the flight vehicle modeling program and its interaction with the user. The main file is the input data file (.Inp) that contains one or more date-sets with the information needed to create vehicle models at fixed flight conditions. Each data-set includes the vehicle mass properties, the aerodynamic data, trajectory data, engine and control surface data, propellant sloshing parameters, sensor data, and if the model is flexible it also includes a set of structural modes. For robustness  $\mu$ -analysis and for developing  $\mu$ -synthesis models for control design the program also requires a data-set with parameter uncertainties. For processing structural flexibility and for selecting structural modes the program requires additional data files from finite element models that have extensions (.Mod, and .Nod). For aero-elastic models that include dynamic coupling between flexibility and aerodynamics and also surface accelerations, the program requires additional GAFD files that have an extension (.Gaf). The program communicates with the user by means of menus and dialogs, but it can also run in batch mode. The program reads the data files, processes the data, and generates the vehicle state-space system at a fixed flight condition. The system is then saved in a systems file that has an extension (.Qdr). The system title is the same as the title included in the vehicle data-set, and the comment lines from the data-set are also copied in the system.

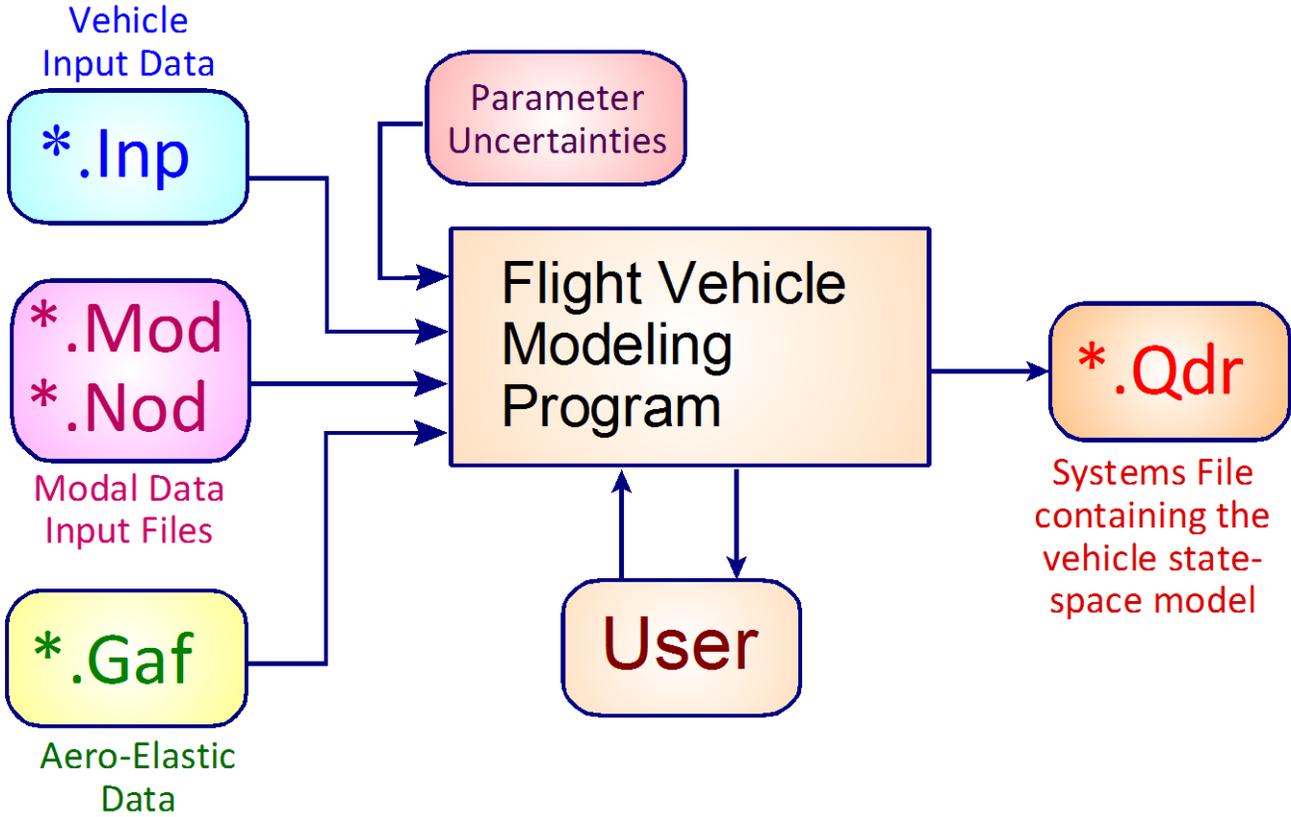


Figure (1) Block Diagram of Flight Vehicle Modeling Program with Input and Output Files

### 3.1 Vehicle Input Data Set

The complexity of the dynamic model and the configuration details are defined in the vehicle input data and in the flags which are set in the input data file (.Inp). An input data file may include more than one set of vehicle data for different applications. For example, a rigid-body set, and a flexible vehicle data-set, that must also include a set of structural modes. A typical flight vehicle data-set is shown below. A vehicle data-set begins with a label id: "FLIGHT VEHICLE INPUT DATA" in the first line which identifies the nature of the data and the flight vehicle modeling program that will process the data. The second line (below the id label) is a title that describes the vehicle type and the flight condition. For example: "Space Shuttle Orbiter Flex Model during Reentry". Then, below the title we have the comment lines that begin with an exclamation mark (!). They are optional and used to provide a short description of the vehicle configuration, the flight condition or the type and purpose of the model and analysis. The comments will also appear in the program dialogs and they are transferred to the state-space model and placed below the title in the systems file (.Qdr). You may include up to 20 comment lines.

The line below the vehicle title and comment lines is the flags line. These are short label flags set by the user, either directly by editing the data-set or they can be set via the FVMP dialog when entering the vehicle data. There are four flag labels, all in one line, that turn on different modeling options.

1. The first flag defines the vehicle rates, and it is either "Body Axes" (default) or "Stability Axes".
2. The second flag defines the type of vehicle attitude in the system outputs. It is either "Attitude=Euler Angles" (default) or "Attitude=Rate Integral", integral of the body rates.
3. The third flag is used to turn-on the aero-elasticity and the inertial coupling data for the aero-surfaces. It is either "Without GAFD" (default) or "Include GAFD" when there is a GAFD data file available.
4. The fourth flag is for turning-on the turn-coordination logic. Sometimes we need to develop a dynamic model of an aircraft for control design purposes that includes the bank-to-yaw turn-coordination cross-coupling in the design model. This is a feed-forward term that commands a yaw rate as a function of the bank angle. It simplifies and separates the two control functions because the gains derived from LQR or H-infinity "assume" that the system already includes turn-coordination. When the flag is set to "With Turn Coordination" the dynamic model includes this cross-coupling term. Otherwise, the default state is: "No Turn Coordination".

```

FLIGHT VEHICLE INPUT DATA .....
Space Shuttle Orbiter Flex Model during Early Re-Entry (for batch)
! The following vehicle model is a Space Shuttle vehicle during the early phase of atmospheric
! re-entry where it is flying at a high angle of attack and it is using both RCS jets and
! control surfaces for attitude control. This set uses an additional file (Shuttle Orb.Gaf) that
! contains the GAFD and inertial coupling coefficients used in modeling aeroelasticity. This
! vehicle set is the same as above, but includes two additional statements at the bottom used
! for selecting GAFD frequencies to match the modal frequencies.
! It also selects GAFD surfaces to match this vehicle surfaces. It requires a GAFD data file.
!
Body Axes Output, Attitude=Euler Angles, Include GAFD, No Turn Coordination

Vehicle Mass (lb-sec^2/ft), Gravity Accelerat. (g) (ft/sec^2), Earth Radius (Re) (ft)      : 7460.4    32.17    0.20896E+08
Moments and products of Inertias Ixx, Iyy, Izz, Ixy, Ixz, Iyz, in (lb-sec^2-ft)         : 804000.0, 7325110.0, 7564300.0, 0.0,
CG location with respect to the Vehicle Reference Point, Xcg, Ycg, Zcg, in (feet)       : -82.85,    0.0,    2.7
Vehicle Mach Number, Velocity Vo (ft/sec), Dynamic Pressure (psf), Altitude (feet)     : 25.0      18640.0  4.0  245500.0
Inertial Acceleration Vo_dot, Sensed Body Axes Accelerations Ax,Ay,Az (ft/sec^2)       : -7.39     -1.14   0.0000   -12.15
Angles of Attack and Sideslip (deg), alpha, beta rates (deg/sec)                     : 40.0      0.0     -0.5     0.0000
Vehicle Attitude Euler Angles, Phi_o,Thet_o,Psi_o (deg), Body Rates Po,Qo,Ro (deg/sec) : 0.0       39.15   0.0     0.0     0.0     0.0
Wind Gust Vel wrt Vehi (Azim & EleV) angles (deg), or Force(lb), Torque(ft-lb), locat:xyz : Gust      45.0    90.0
Surface Reference Area (feet^2), Mean Aerodynamic Chord (ft), Wing Span in (feet)      : 2680.0    35.0,    79.0
Aero Moment Reference Center (Xmrc,Ymrc,Zmrc) Location in (ft), {Partial_rho/ Partial_H} : -81.36,   0.0,    2.97,    -2.07e-10
Aero Force Coef/Deriv (1/deg), Along -X, {Cao,Ca_alf,PCa/PV,PCa/Ph,Ca_alfdot,Ca_q,Ca_bet} : 0.103,    -0.007, -0.4e-6, 0.8e-7,0.0,
Aero Force Coefficient/Derivat (1/deg), Along Y, {Cy0,Cy_bet,Cy_r,Cy_alf,Cy_p,Cy_betdot,Cy_V} : 0.0,     -0.023, 0.39, 0.0, -0.54, 0.0,
Aero Force Coef/Deriv (1/deg), Along Z, {Czo,Cz_alf,Cz_q,Cz_bet,PCz/Ph,Cz_alfdot,PCz/PV} : -2.6,    -0.086, -1.7, 0.0, 0.0, 0.0,
Aero Moment Coef/Derivat (1/deg), Roll: {Clo, Cl_beta, Cl_betdot, Cl_p, Cl_r, Cl_alfa} : 0.0,     -0.007, 0.0, -0.65, 0.25,
Aero Moment Coef/Deriv (1/deg), Pitch: {Cmo,Cm_alfa,Cm_alfdot,Cm_bet,Cm_q,PCm/PV,PCm/Ph} : 0.0012,  -0.008, 0.0, 0.0, -17.4,
Aero Moment Coefficient/Derivat (1/deg), Yaw : {Cno, Cn_beta, Cn_betdot, Cn_p, Cn_r, Cn_alfa} : 0.0,     -0.0011, 0.0, 0.26, -1.1,

```