SECTION 2

SYSTEMS DATA

INTRODUCTION.

Systems data include description of operations, component description and design data, and operational limitations and restrictions. Subsection 2.1 describes the overall spacecraft navigation, guidance, and control requirements and the resultant systems interface. Subsections 2.2 through 2.10 present data grouped by spacecraft systems, arranged in the following order: guidance and navigation, stabilization and control, service propulsion, reaction control, electrical power, environmental control, telecommunications, sequential, and caution and warnings. Subsection 2.11 deals with miscellaneous systems data. Subsection 2.12 deals with crew personal equipment. Subsection 2.13 deals with docking and crew transfer.

G&C

SECTION 2

SUBSECTION 2.1

GUIDANCE AND CONTROL

2.1.1 GUIDANCE AND CONTROL SYSTEMS INTERFACE.

The Apollo guidance and control functions are performed by the primary guidance, navigation, and control system (PGNCS), and stabilization and control system (SCS). The PGNCS and SCS systems contain rotational and translational attitude and rate sensors which provide discrete input information to control electronics which, in turn, integrate and condition the information into control commands to the spacecraft propulsion systems. Spacecraft attitude control is provided by commands to the reaction control system (RCS). Major velocity changes are provided by commands to the service propulsion system (SPS). Guidance and control provides the following basic functions:

- Attitude reference
- Attitude control
- Thrust and thrust vector control.

The basic guidance and control functions may be performed automatically, with primary control furnished by the command module computer (CMC) or manually, with primary control furnished by the flight crew. The subsequent paragraphs provide a general description of the basic functions.

2.1.2 ATTITUDE REFERENCE.

The attitude reference function (figure 2.1-1) provides display of the spacecraft attitude with reference to an established inertial reference. The display is provided by two flight director attitude indicators (FDAI) located on the main display console, panels 1 and 2. The displayed information consists of total attitude, attitude errors, and angular rates. The total attitude is displayed by the FDAI ball. Attitude errors are displayed by three needles across scales on the top, right, and bottom of the apparent periphery of the ball. Angular rates are displayed by needles across the top right, and bottom of the FDAI face.

Total attitude information is derived from the IMU stable platform or the gyro display coupler (GDC). The IMU provides total attitude by maintaining a gimbaled, gyro-stabilized platform to an inertial reference orientation. The GDC provides total attitude by updating attitude information with angular rate inputs from gyro assembly 1 or 2. Both the IMU and the GDC furnish total attitude data to the command module computer (CMC) as well as to the FDAIs.

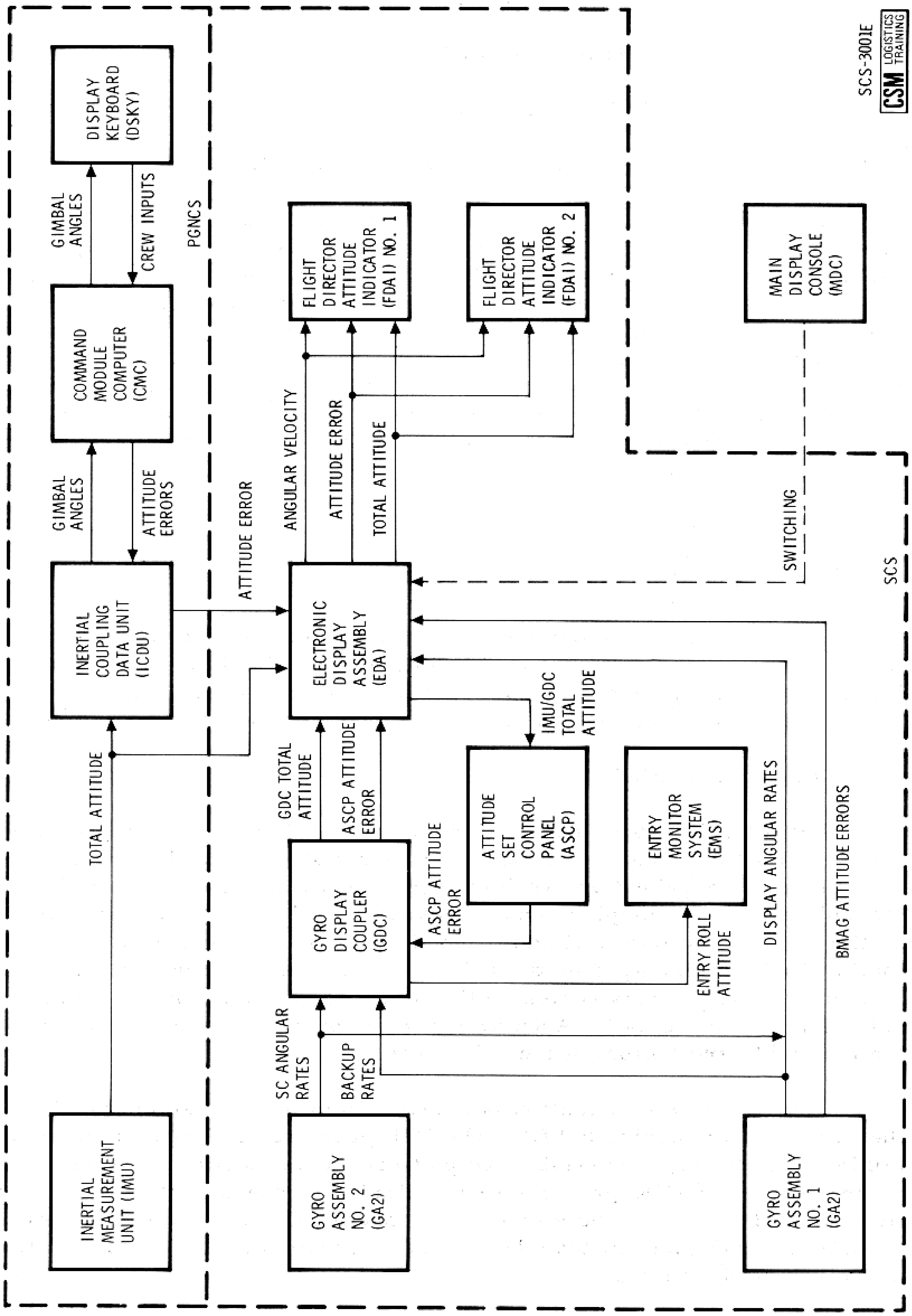

Figure 2.1-1. G&C Attitude Reference

Attitude error information is derived from three sources. The first source is from the IMU through the coupling data unit (CDU) which compares IMU gimbal angles with CMC commanded angles set into the CDU. Any angular difference between the IMU gimbals and the CDU angles is sent to the FDAI for display on the attitude error needles. The second source is from gyro assembly 1 which contains three (one for each of the X, Y, and Z axes) single-degree-of-freedom attitude gyros. Any spacecraft rotation about an axis will offset the case of a gyro from the float. This rotation is sensed as a displacement off null, and a signal is picked off which is representative of the magnitude and direction of rotation. This signal is sent to the FDAI for display on the attitude error needles. The third source is from the GDC which develops attitude errors by comparing angular rate inputs from gyro assembly 1 or 2 with an internally stored orientation. This data is sent to the FDAI for display on the attitude error needles.

Angular rates are derived from either gyro assembly 1 or 2. Normally, the No. 2 assembly is used; however, gyro assembly 1 may be switched to a backup rate mode if desired. For developing rate information, the gyros are torqued to null when displaced; thus, they will produce an output only when the spacecraft is being rotated. The output signals are sent to the FDAI for display on the rate needles and to the GDC to enable updating of the spacecraft attitude.

2.1.3 ATTITUDE CONTROL.

The attitude control function is illustrated in figure 2.1-2. The control may be to maintain a specific orientation, or to command small rotations or translations. To maintain a specific orientation, the attitude error signals, described in the preceding paragraph, are also routed to the control reaction jet on-off assembly. These signals are conditioned and applied to the proper reaction jet which fires in the direction necessary to return the spacecraft to the desired attitude. The attitude is maintained within specified deadband limits. The deadband is limited within both a rate and attitude limit to hold the spacecraft excursions from exceeding either an attitude limit or angular rate limit. To maneuver the spacecraft, the reaction jets are fired automatically under command of the CMC or manually by flight crew use of the rotation control. In either case, the attitude control function is inhibited until the maneuver is completed. Translations of small magnitude are performed along the +X axis for fuel settling of SPS propellants prior to burns, or for a backup deorbit by manual commands of the translation control. An additional control is afforded by enabling the minimum impulse control at the lower equipment bay. The minimum impulse control produces one directional pulse of small magnitude each time it is moved from detent. These small pulses are used to position the spacecraft for navigational sightings.

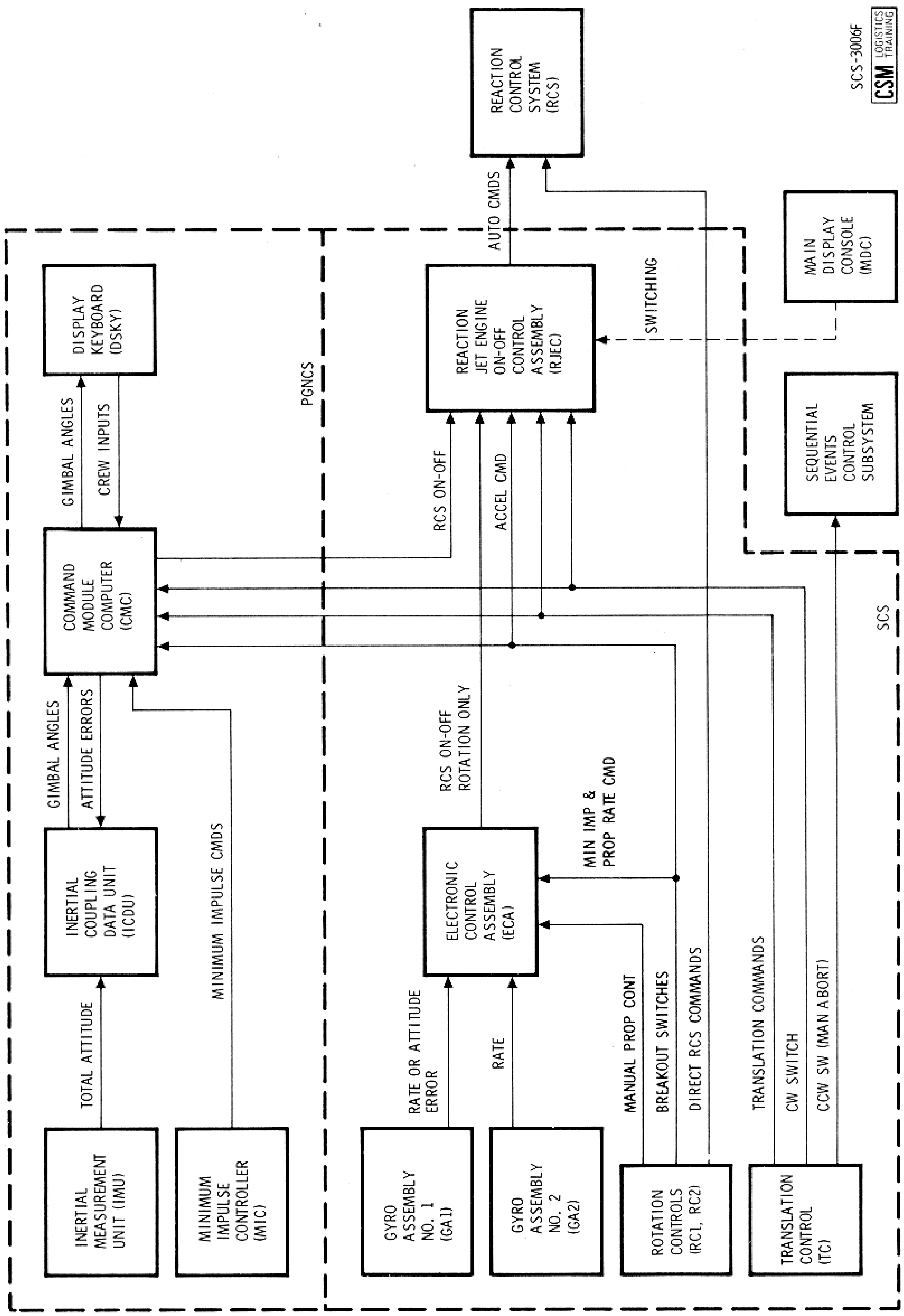

Figure 2.1-2. G&C Attitude Control

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2.1.4 THRUST AND THRUST VECTOR CONTROL.

The guidance and control system provides control of two thrust functions (figure 2.1-3). The first is control of the SPS engine on-off time to control the total magnitude of thrust applied to the spacecraft. Primary control of thrust is through the CMC. The thrust-on time, magnitude of thrust desired, and thrust-off signal are preset by the flight crew, and performed in conjunction with the CMC. The value of velocity change attained from the thrust is derived by monitoring accelerometer outputs from the IMU. When the desired velocity change has been achieved, the CMC removes the thrust-on signal. Secondary thrust control is afforded by the velocity counter portion of the entry monitor subsystem. The counter is set to the value of desired thrust prior to the engine on signal. Velocity change is sensed by a +X axis accelerometer which produces output signals representative of the velocity change. These signals drive the velocity counter to zero which terminates the engine on signal. In either case, the actual initiation of thrust is performed by the flight crew. There is a switch for manual override of the engine on and off signals.

Thrust vector control is required because of center-of-gravity shifts caused by depletion of propellants in the SPS tanks. Thrust vector control is accomplished by electromechanical actuators to position the gimbal-mounted SPS engine. Automatic thrust vector control (TVC) commands may originate in the PGNCS or SCS systems. In either case, the pitch and yaw attitude error signals are removed from the RCS system and applied to the SPS engine gimbals. Manual TVC is provided to enable takeover of the TVC function if necessary. The MTVC is enabled by twisting the translation control to inhibit the automatic system, and enables the rotation control which provides command signals for pitch and yaw axes to be applied to the gimbals. The initial gimbal setting is accomplished prior to the burn by positioning thumbwheels on the fuel pressure and gimbal position display.

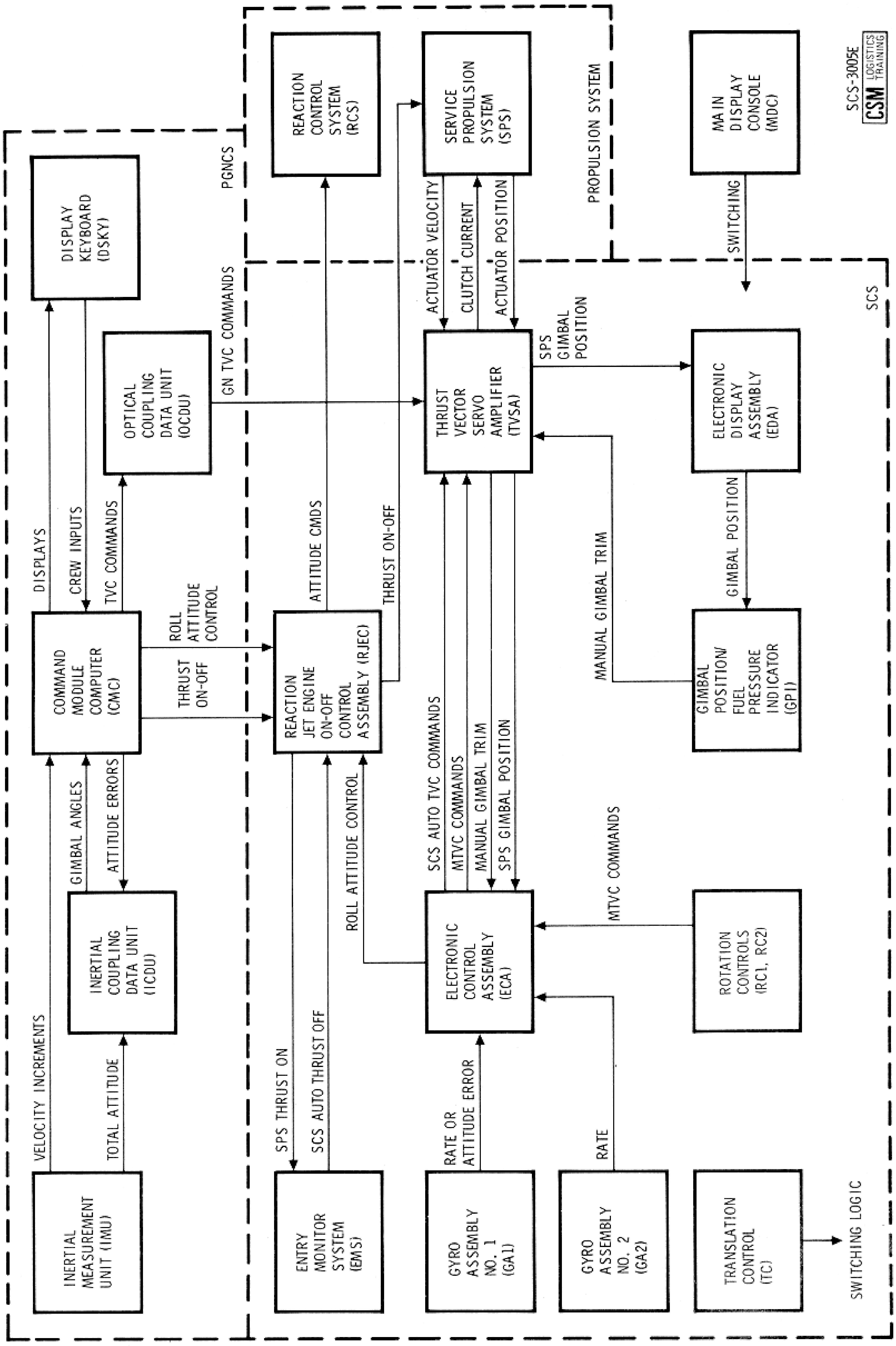

Figure 2.1-3. G&C Thrust Vector Control