SPACE STATION MOMENTUM MANAGEMENT

V. Buckalew, Miriam Hopkins, NASA/Marshall Space Flight Center

Gravity gradient stabilization is planned for the space station. Torques arise from air-drag since the center of pressure is not the same as the center of mass of the satellite. The magnitude of these torques varies depending upon the orientation of the solar panels. Adjustments are made through the use of CMG's (Control Moment Gyros). In time, if the CMG's saturate, torque must be bled off using thrusters; however, that is undesirable because it expends propellant and contaminates the local environment. The task of the engineer is to design the CMG's to handle the aerodynamic torques and design the configuration of the spacecraft to prevent, if possible, CMG saturation. For this application the long-term atmospheric density trends are of less importance than the rate of change of density within an orbit. In principle CMG's could be designed for the worst case of maximum solar activity, but the penalty for overdesign is excess mass and cost.

In summary, present models are inadequate for this application with the greatest need being a reliable prediction of maximum rates-of-change of density within an orbit.

NASA

George C. Marshall Space Flight Center

WORKSHOP ON UPPER AND MIDDLE ATMOSPHERIC DENSITY

MODELING REQUIREMENTS FOR SPACECRAFT DESIGN AND OPERATIONS

SPACE STATION CONTROL

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SYSTEMS DYNAMICS LABORATORY
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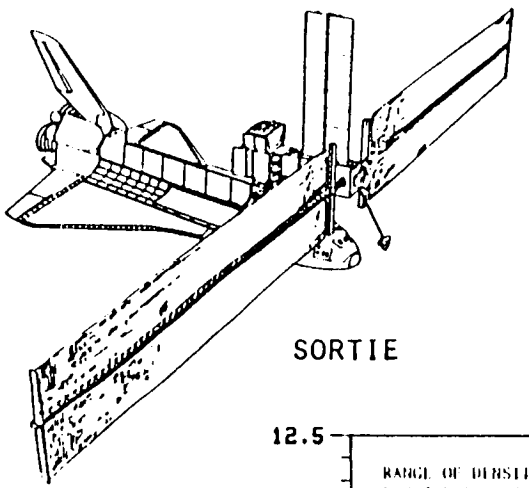
NOVEMBER 1985

SPACE STATION CONTROL

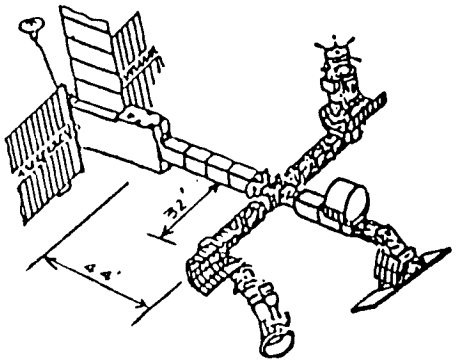
BACKGROUND

- WITH ADVENT OF LARGE AREA SPACECRAFT IN LOW EARTH ORBIT, AERODYNAMIC TORQUE BECOMES A DOMINANT DISTURBANCE.
    - CONFIGURATION
    - ATTITUDE REQUIREMENTS
    - DESIGN DENSITY
        - MAGNITUDE
        - PROFILE
- AERODYNAMIC DOMINANCE EXEMPLIFIED BY CONTROL REQUIREMENT ANALYSES FOR 25Kw SPACE PLATFORM.
    - CMG SIZING REQUIREMENTS VERY NEARLY PROPORTIONAL TO DESIGN DENSITY.

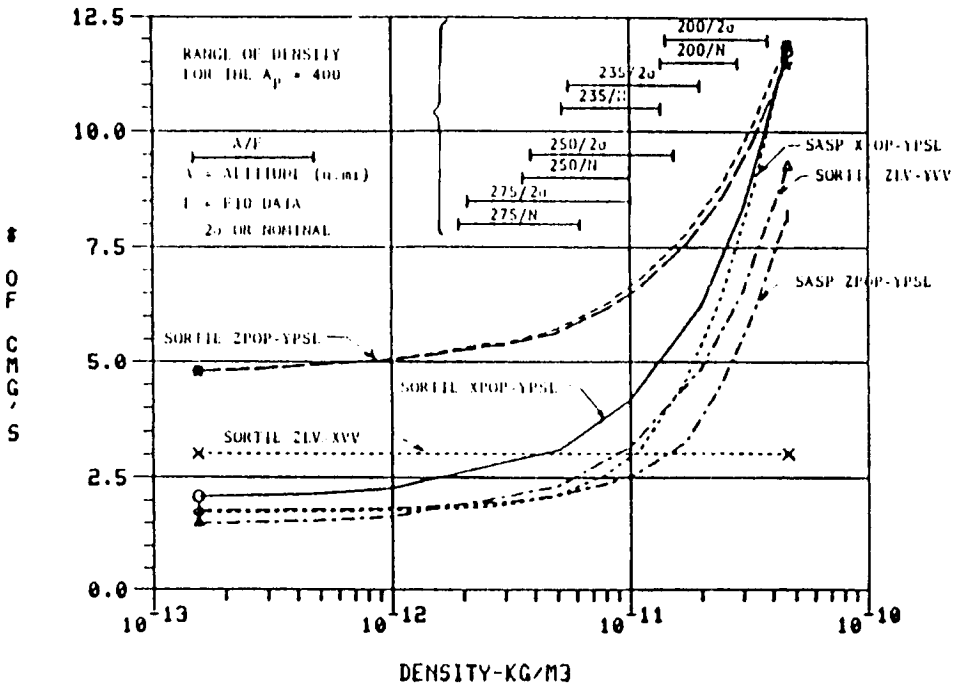
SPACE STATION CONTROL



SORTIE



SCIENCE AND APPLICATION SPACE PLATFORM
(SASP)



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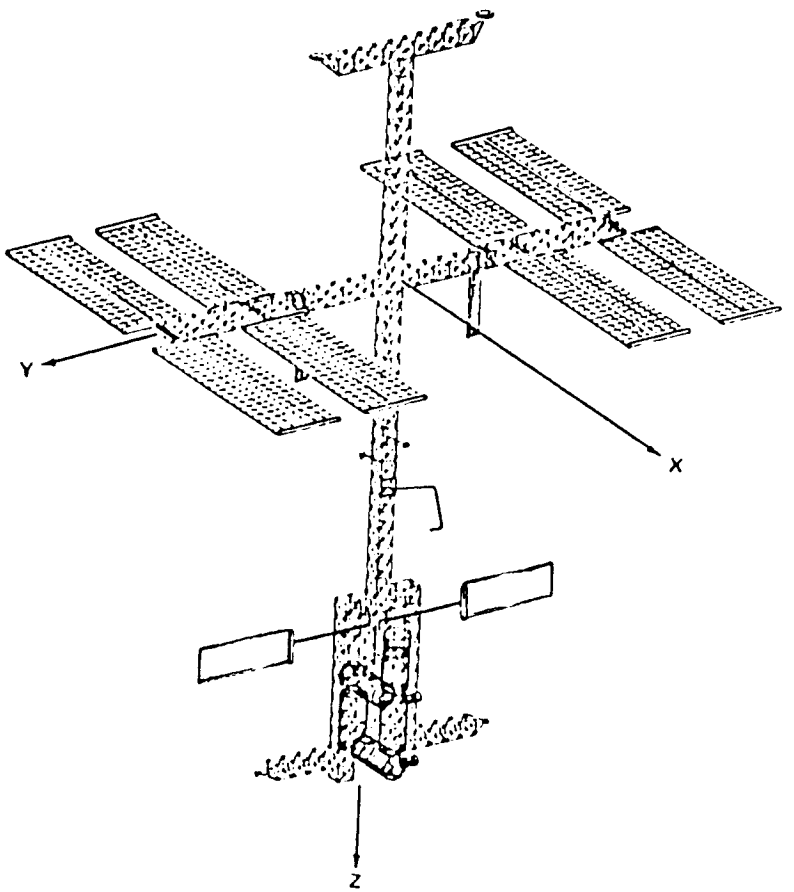
OF POOR QUALITY

SPACE STATION CONTROL



SINGLE KEEL SPACE STATION

- BASELINE ATTITUDE FOR SPACE STATION HAS LONGITUDINAL AXIS EARTH POINTING WHILE SOLAR ARRAYS REMAIN SUN POINTING.
- BOTH AERODYNAMIC AND GRAVITY GRADIENT TORQUES VARY AS ARRAYS ROTATE.
- MOMENTUM MANAGEMENT SCHEME SEEKS MINIMUM TORQUE AVERAGE ATTITUDE.

- TO PREVENT CMG SATURATION, ESTIMATE OF DESIRED TILT ANGLES REQUIRED DURING BUILDUP.

- PAYLOAD COMMUNITY MAY REQUIRE ORBITS/DAYS AT CONSTANT ATTITUDE.

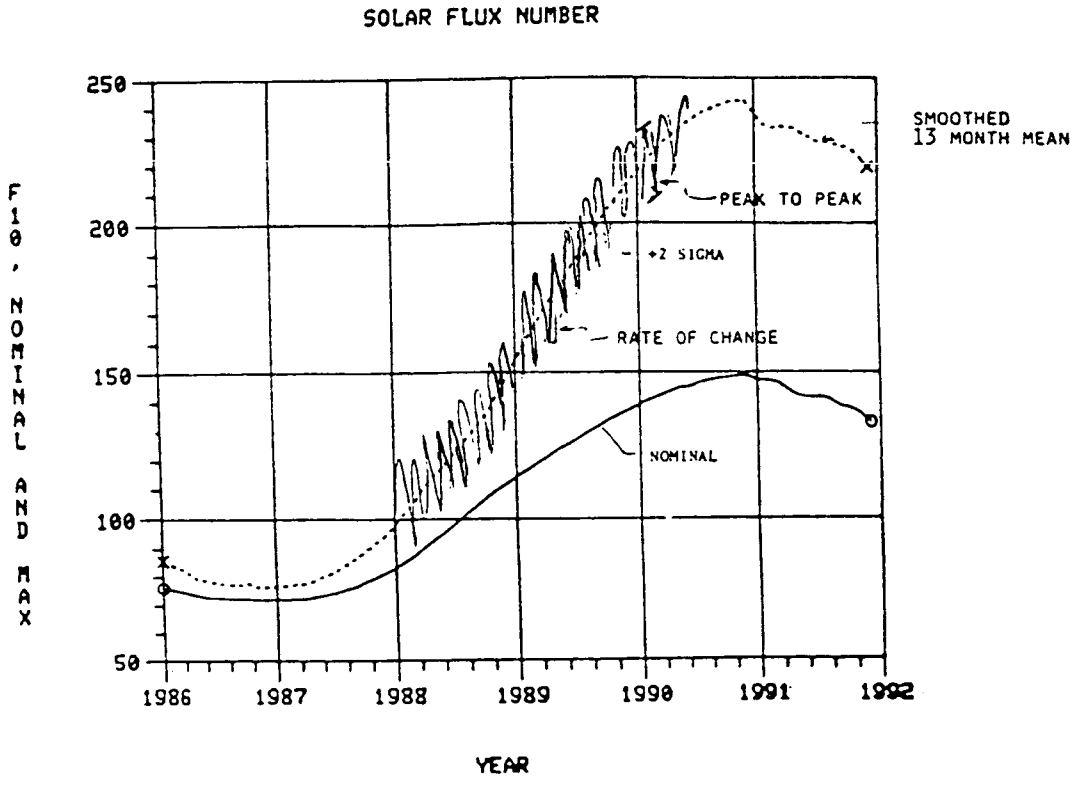
- HOW WELL DOES ATMOSPHERE MODEL REFLECT DAY TO DAY VARIATIONS?

- CONTROL SIMULATIONS USE MSFC/J70 ATMOSPHERIC DENSITY MODEL.

  BASELINE INPUT

  $F_{10.7} = \bar{F}_{10.7} = 230$

  $A_P = 140$



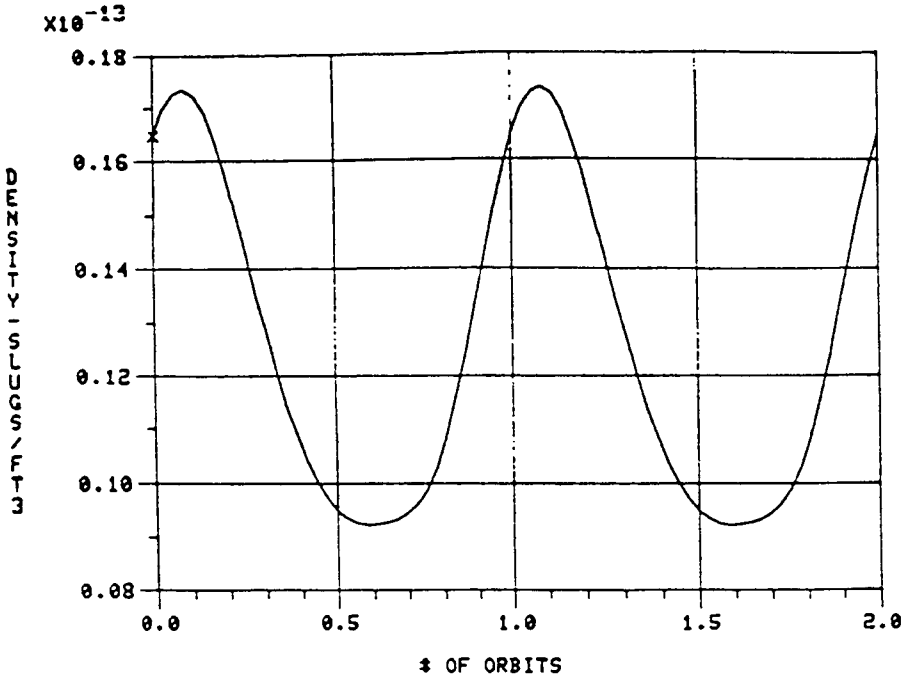
CONTROL DESIGNER IS

- o NOT CONCERNED WITH 13 MONTH SMOOTHED MEAN (AT LEAST DIRECTLY).
- o THE SMOOTHED MEAN PLUS THE PEAK TO PEAK VARIATION DICTATE SYSTEM SIZING REQUIREMENTS AND ESTIMATES TO USERS OF PROBABLY TILT ANGLES OFF NOMINAL ATTITUDE.
- o RATE OF CHANGE OF DENSITY ON A PER ORBIT BASIS IS THE PRIMARY CONCERN. DICTATES THE ROBUSTNESS REQUIRED. GENERALLY NEED TO KNOW ONLY THE MAX VALUE.
- o OTHERWISE DESIGNER IS RELATIVELY INSENSITIVE TO THE DIFFERENCE BETWEEN THE MODEL AND THE ACTUAL DENSITY ON A DAY BY DAY BASIS.

THE FOLLOWING SERIES OF CHARTS WILL ILLUSTRATE

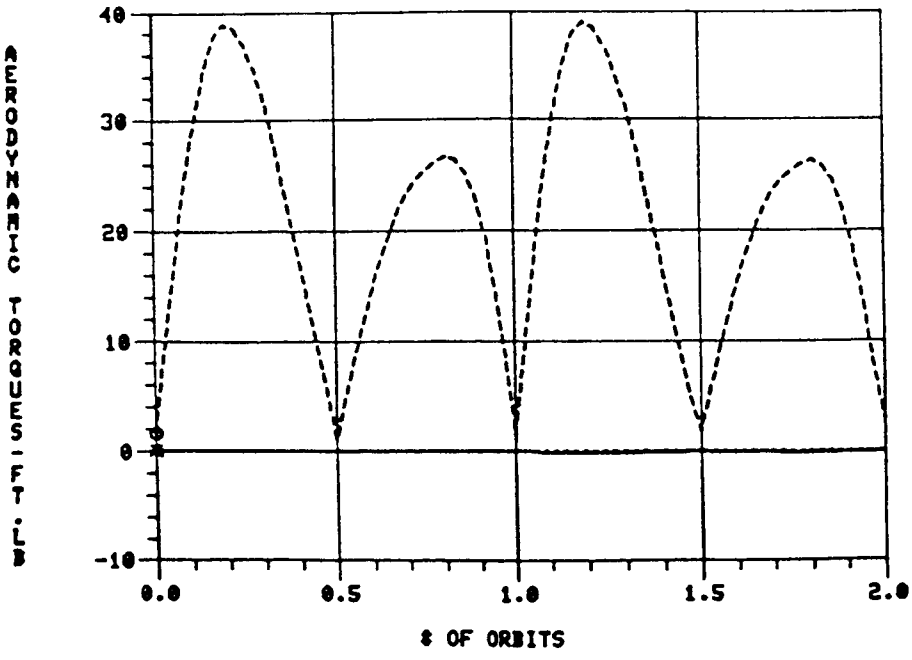
- o DENSITY ENCOUNTERED AND RESULTING AERODYNAMIC TORQUES FOR A REFERENCE CASE.
- o OUT-OF-PLANE (OP) AND IN PLANE (IP) TILT ANGLES DETERMINED BY MOMENTUM MANAGEMENT SCHEME AND RESULTING MOMENTUM.
- o COMPARISON OF MOMENTUM STORAGE REQUIREMENTS WITH AND WITHOUT ACTIVE SCHEME.
- o CHANGE IN TILT ANGLE REQUIREMENT FOR TWO STATIC CONDITIONS OF DENSITY.
- o SYSTEM PERFORMANCE DURING HYPOTHITICAL MAGNETIC STORM WHERE AVERAGE DENSITY INCREASES WITH TIME.
- o MOMENTUM STORAGE REQUIREMENTS WITHOUT ONBOARD ADAPTIVE MOMENTUM MANAGEMENT.

TYPICAL DENSITY AND AERODYNAMIC PROFILES



$F_{10.7} = \bar{F}_{10.7} = 230$

$A_p = 140$

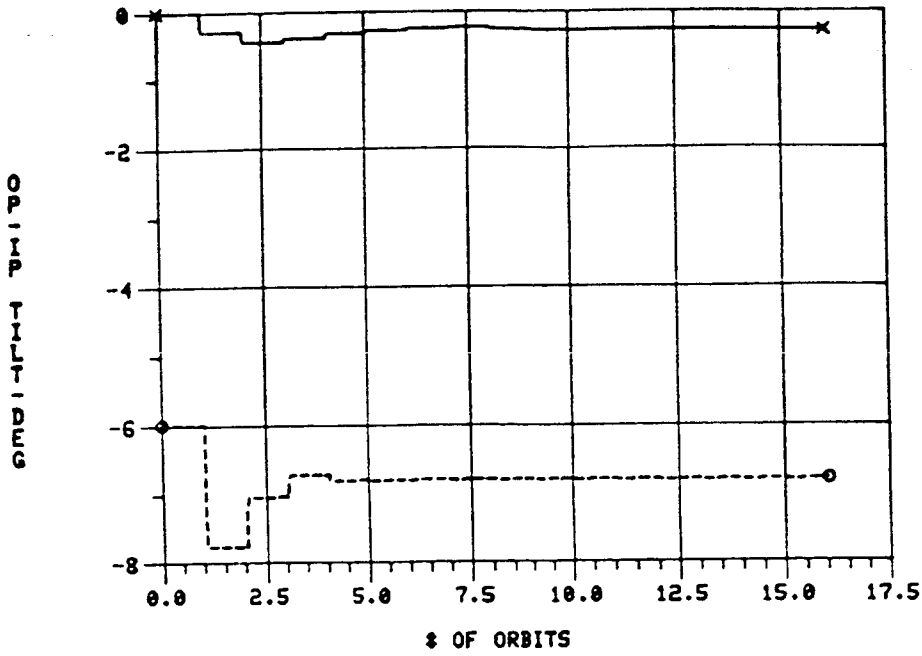


TILT IC's

OP = 0°

IP = -6°

TILT ANGLES AND RESULTING MOMENTUM



OP TILT

IP TILT

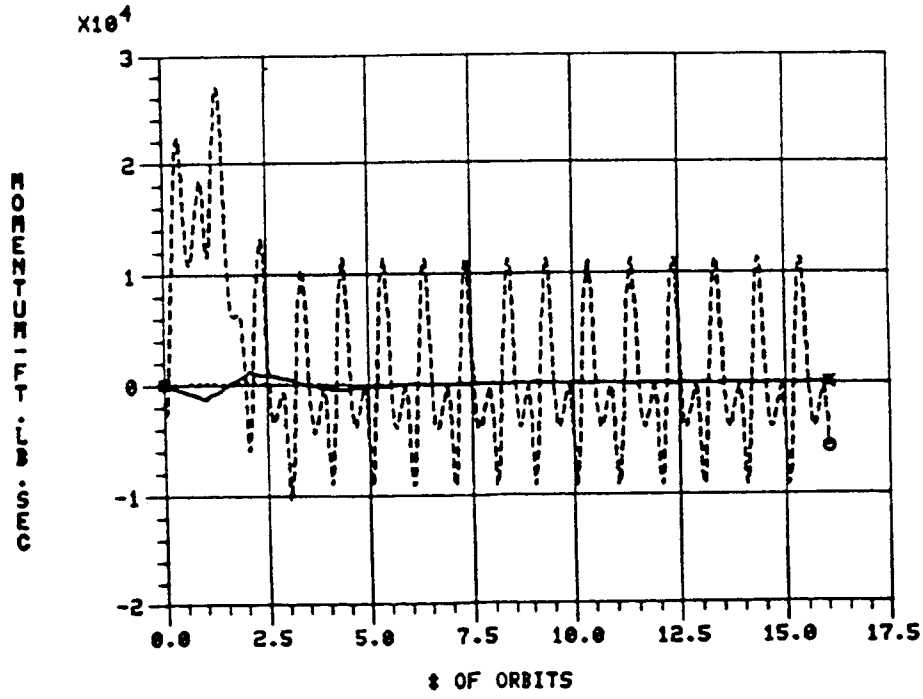
$F_{10.7} = \bar{F}_{10.7} = 230$

$A_p = 140$

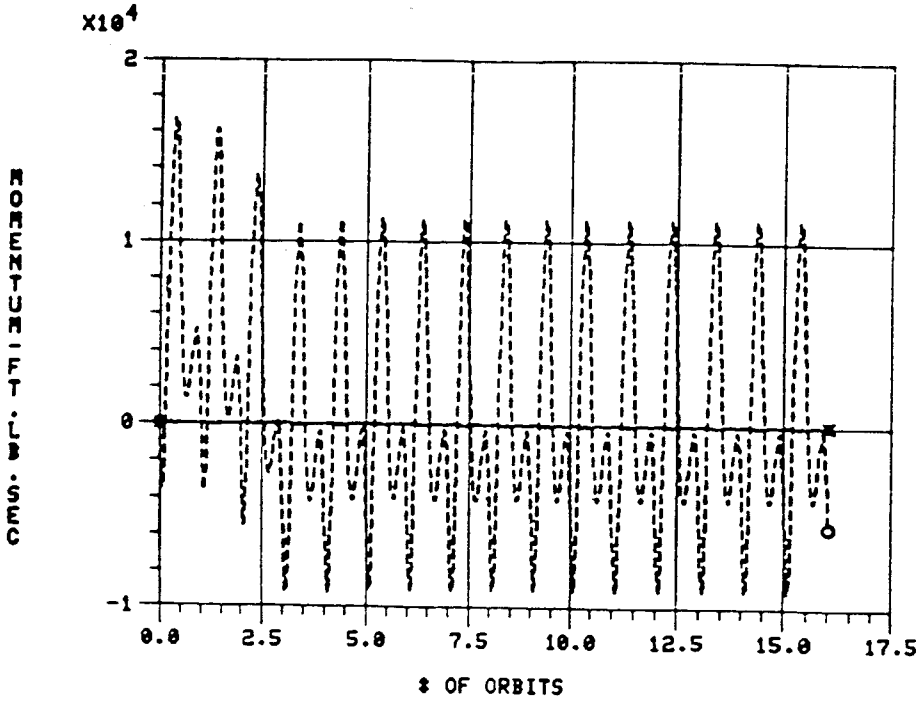
TILT IC's

OP = 0°

IP = -6°



MOMENTUM REQUIREMENTS WITH AND WITHOUT ACTIVE CONTROL



WITH ACTIVE CONTROL

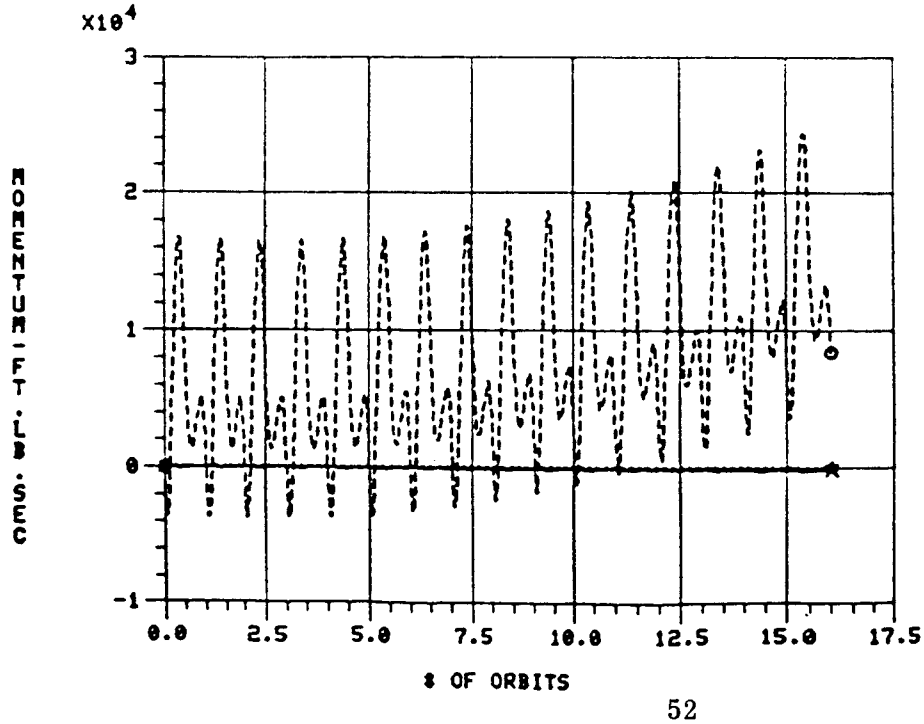
$F_{10.7} = \bar{F}_{10.7} = 230$

$A_p = 140$

TILT IC's

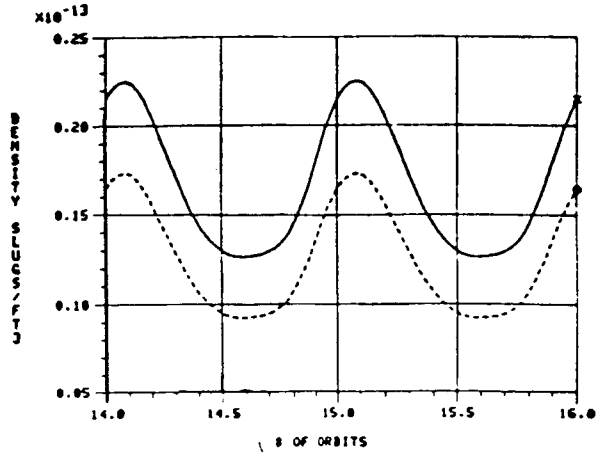
OP = -.30°

IP = -6.8°



WITHOUT ACTIVE CONTROL

EFFECT OF DAILY SOLAR FLUX INCREASE

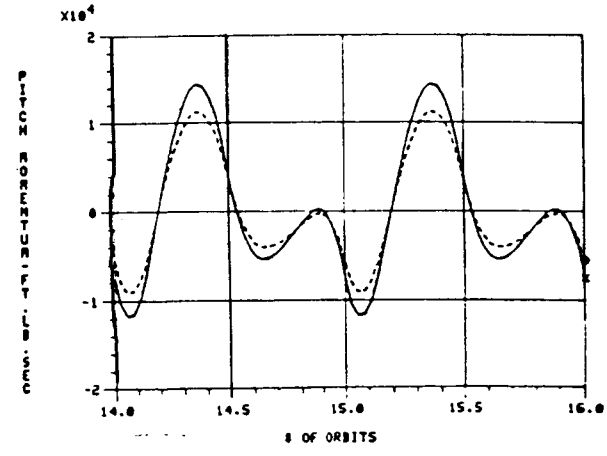


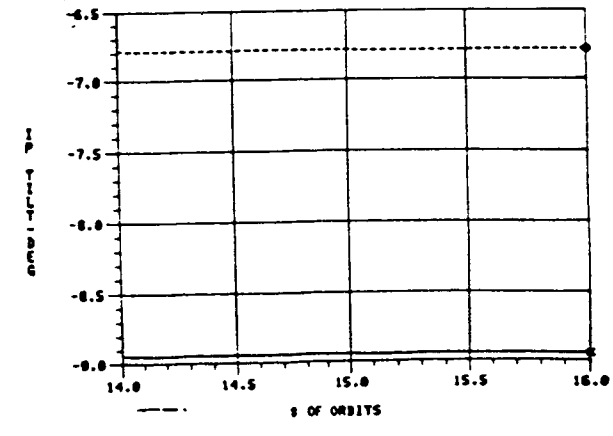
$F_{10.7}$ =315, $\bar{F}_{10.7}$ = 230

A_p = 140

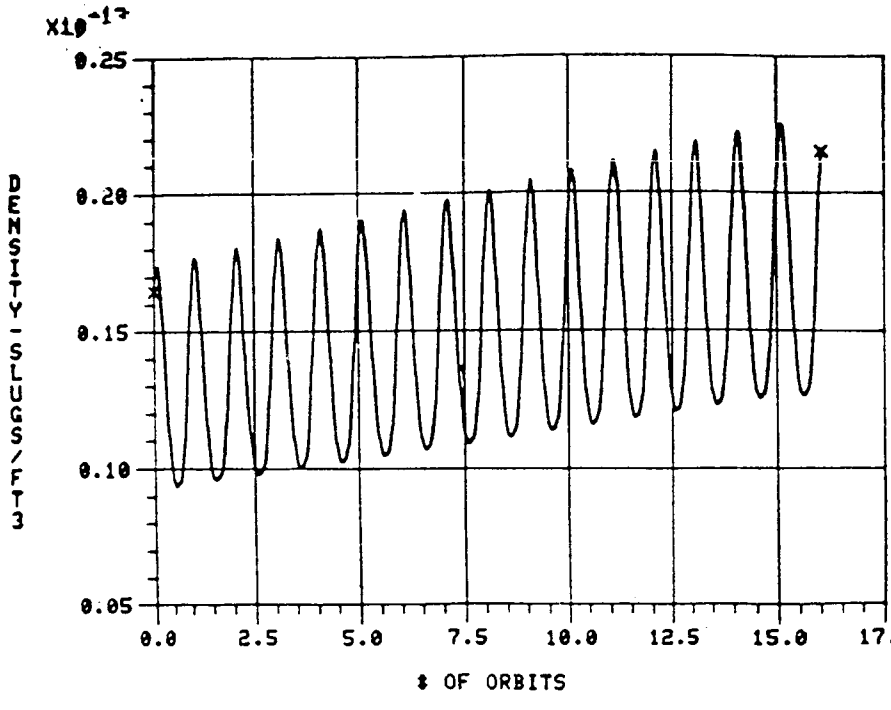
$F_{10.7} = \bar{F}_{10.7}$ = 230

A_p = 140





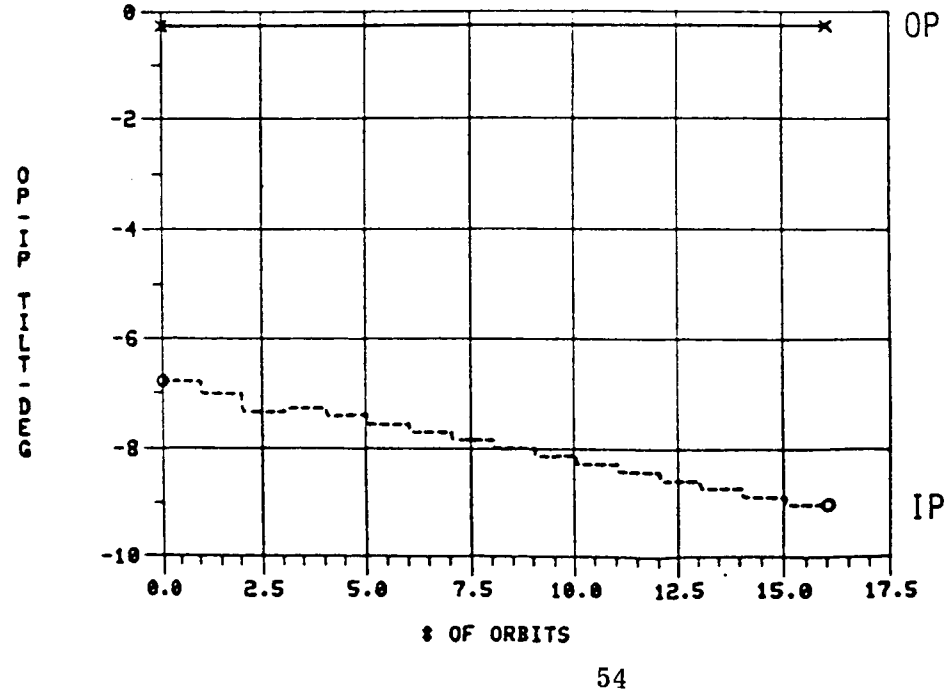
EFFECT OF GEOMAGNETIC ACTIVITY INCREASE



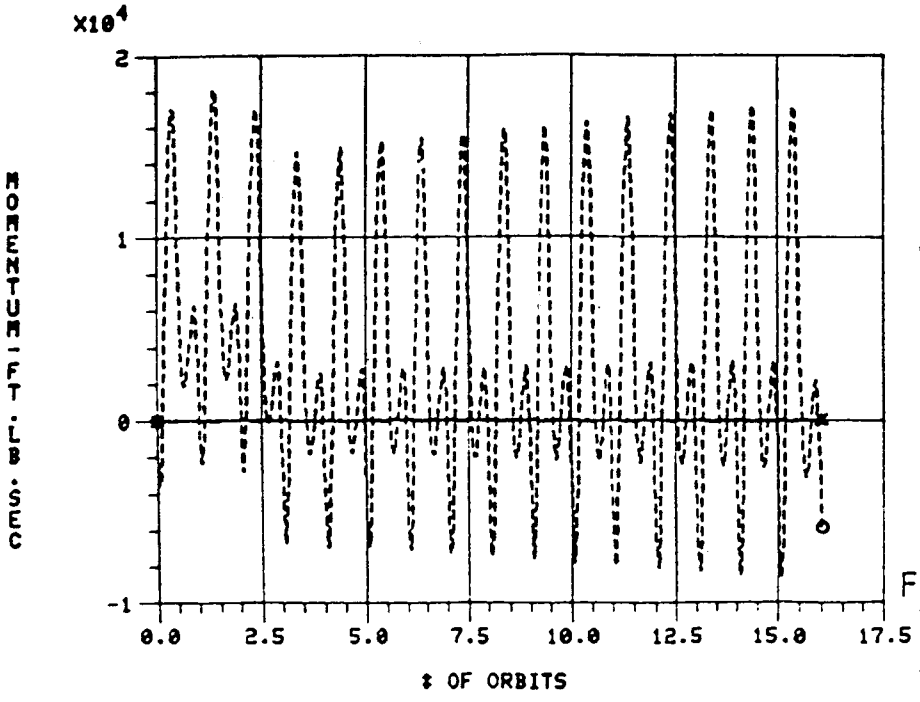
$F_{10.7} = \bar{F}_{10.7} = 230$

A_p = 140 TO 400 OVEI
15 ORBIT PERIOD

TILT IC's
OP = -.3°
IP = -6.8°



MOMENTUM CHANGES DUE TO INCREASE
IN GEOMAGNETIC ACTIVITY

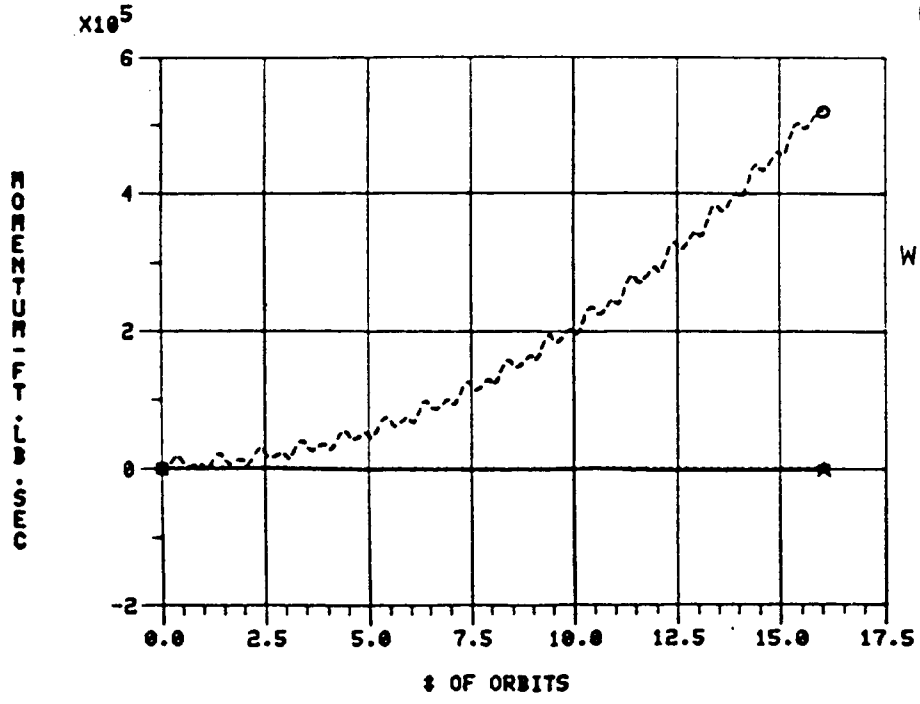


WITH ACTIVE CONTROL

$F_{10.7} = \bar{F}_{10.7} = 230$

A_p = 140 TO 400 OVER
15 ORBIT PERIOD

TILT IC's
OP = -.3°
IP = -6.8°



WITHOUT ACTIVE CONTROL

SUMMARY

- o CONTROL REQUIREMENTS FOR SPACE STATION AND ASSOCIATED PLATFORMS HEAVILY INFLUENCED BY AERODYNAMIC TORQUES.
- o DEGREE OF SENSITIVITY IS COMBINATION OF CONFIGURATION, ATTITUDE REQUIREMENTS AND ATMOSPHERIC DENSITY.
- o AERODYNAMIC TORQUES FOR CURRENT DUAL KEEL SPACE STATION REDUCED BECAUSE OF SMALLER MOMENT ARM.

CONCERN

- SPACE STATION CONTROL SYSTEM REQUIREMENTS DEPEND ON TRANSIENT EFFECT OF DENSITY. CURRENT MODEL DOES NOT REFLECT THESE TRANSIENTS BUT RELIES ON MAGNIFICATION OF STEADY STATE ATMOSPHERE TO COVER EVERYTHING. AN ATMOSPHERIC DENSITY MODEL WHICH INCLUDES TRANSIENT EFFECTS IS NEEDED.