- Steve Shawger

  AXAF Maneuvers a Lot, So Do Gyro Scale Factor / Alignment Calibration Without Doing Special Calibration Maneuvers. Use Kalman Filter Algorithm or Something About As Good

- Reid Reynolds

  Ground Kalman Filter + 12/94 Target Data → 85-95 sec Maneuver Error

  Baseline Ground Cal Algorithm + 12/94 Target Data → 200 - 520 sec " "

- Patrick Slane

  12/94 Target Data Not Conservative

- Michael Garcia

  ± 133 sec Search Box → ≥ 2 Acq. Stars in 98% of Sky
  ± 200 90
  ± 267 65

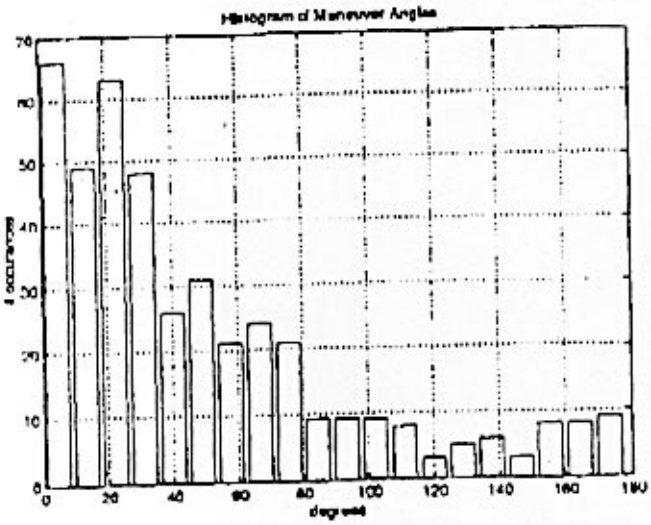
- Conclusion

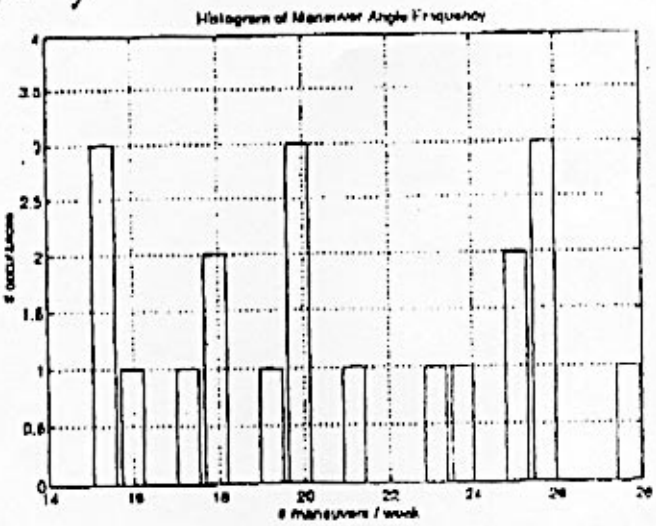
  It Looks Bad for Scheduling the Mission Without ~~Regard to~~ Considering Gyro Cal Observability

  Baseline Ground Cal Algorithm Doesn't Work Well as a "Filter"

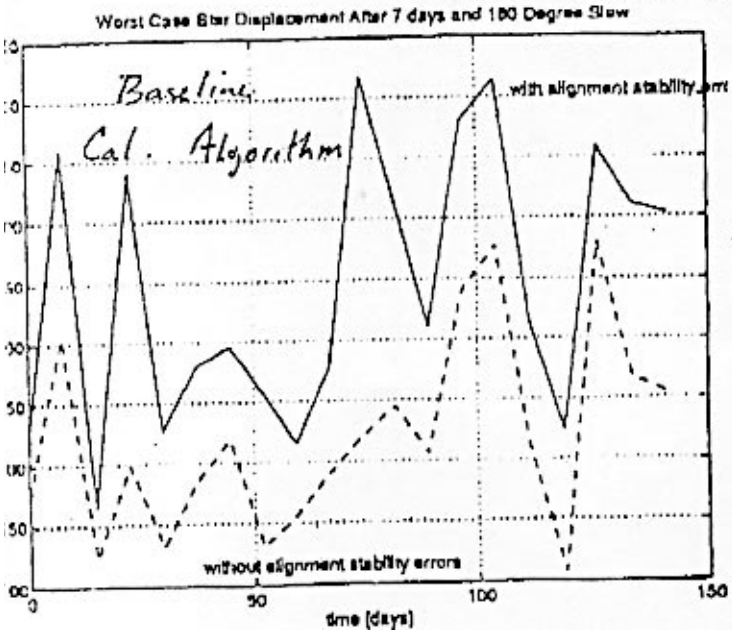
Maneuver Error Analysis from PCAD CDA

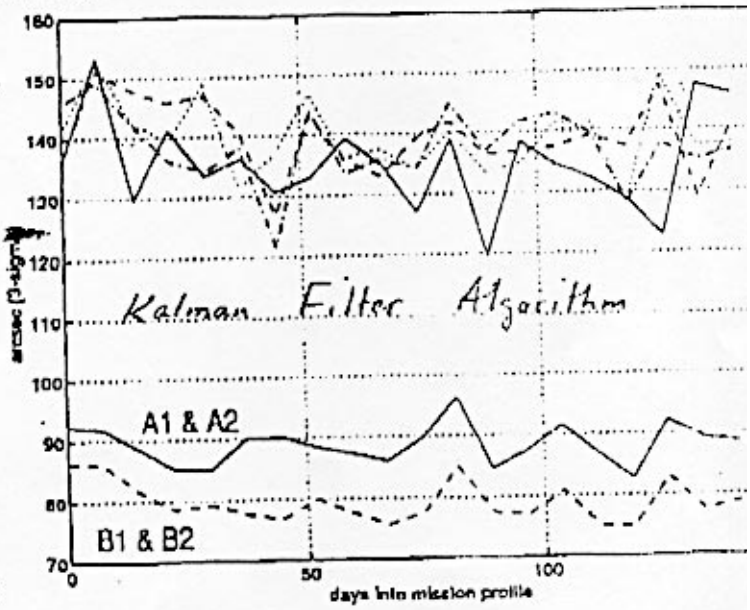
12/94 Targeting Data





180° Slew Errors





Error Budget for 180° Maneuver Error

assumptions 1) maneuver occurs 2 months after last calibration
2) at least 30 minutes of Kalman filter settling before maneuver begins

(A) Scale factor nonlinearity 50 ppm — 32.4 sec

(B) Gyro bias error at beginning of maneuver — 13

(B1) - ½ hr Kalman filter settling before maneuver — 13 sec
(B2) - 500 sec " " " " " — 50 sec
(B3) - R Reynolds CDA analysis (5 sec/hr) × 1 hr " — 5 sec

(C) gyro noise and change in gyro bias during maneuver — 6

(C1) $3(\sigma_v^2 t + \sigma_u^2 t^3/3)^{1/2}$ $\sigma_v = .019$ sec/sec$^{1/2}$, $\sigma_u = 1.33 \cdot 10^{-5}$ sec/sec$^{3/2}$, $t = 3600$ sec

(D) Scale factor/alignment calibration error — 77.2 — 189.6

(D1) $\sim \frac{77.2}{100}\begin{bmatrix} 330 & 250 & 250 \\ 250 & 160 & 300 \\ 250 & 300 & 160 \end{bmatrix} \times 10^{-6}$ or $\sim \frac{189.6}{100}\left[\quad\right]$

(E) Change in scale factor/alignment since calibration

(E1) scale factor $(425 \text{ ppm}/\sqrt{9 \text{ yr}})(\sqrt{2 \text{ mo}}) \times (.648 \text{ sec/ppm}) =$ — 37.5

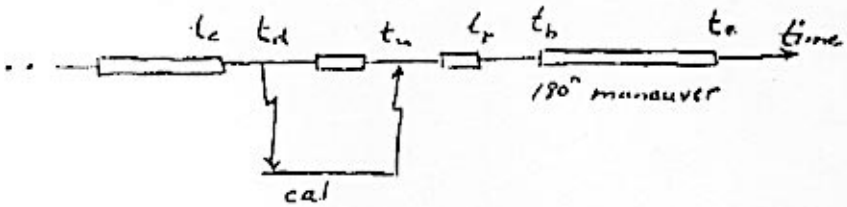
(E2.1) IRU/ACA alignment
(E2.11) - (18.3 sec) × 2 = 36.6 sec, (426 sec) × 2 = 85.2 sec — 36.6
(E2.12) - CDA analysis $(12.0 \text{ sec}/\sqrt{3 \text{ days}})(\sqrt{2 \text{ mo}}) \times 2 = 107.1$ sec

(E2.2) IRU internal alignment
(E2.21) - $(20 \text{ sec}/\sqrt{9 \text{ yr}}) \times (\sqrt{2 \text{ mo}}) \times 2 =$ 5.4 sec — 5.4
(E2.22) - CDA analysis $(9.0 \text{ sec}/\sqrt{3 \text{ days}})(\sqrt{2 \text{ mo}}) \times 2 = 80.5$ sec

(E23) ACA internal alignment $(3 \text{ sec}/\sqrt{6 \text{ mo}})(\sqrt{2 \text{ mo}}) \times 2 = 3.5$ sec — 3.5

DSS Above — 100 sec, 200 sec

Timeline



— = maneuver

t_d = downlink time

t_u = uplink time

t_b = begin 180° maneuver time

t_e = end 180° maneuver time

t_c = end of last maneuver used for the calibration

t_p = end of maneuver preceding 180° maneuver

3.2.3.8.2 ASDR STABILITY

The maximum allowed change in ASDR is less than 0.125 deg/hr/g per month. The largest change during the Zodiaque program was under 0.1 deg/hr/g per month with the average under 0.042 deg/hr/g per month.

3.2.3.9 NOISE EQUIVALENT ANGLE

The noise equivalent angle requirement for Zodiaque was the same as for AXAF-I IRU, 0.36 arc-sec over a 100 second interval. The five Zodiaque units had an average of less than 0.2305 arc-sec.

ALIGNMENT STABILITY: EQ SPEC 3.2.7.5.2.2 LONG TERM.

AXAF-I ALIGNMENT STABILITY

SOURCE	ARC-SEC 3 σ	COMMENTS
PYROTECHNIC SHOCK	10	ZODIAQUE VALUE
RANDOM VIBRATION	11	ZODIAQUE VALUE
AGING	18.2	ZODIAQUE VALUE OF 22 ADJUSTED BY √9.6 YRS/14 YRS
RSS	23.5	
SPECIFICATION	100	

only this value pertinent to SF/MA stability

SHORT TERM AXAF-I ALIGNMENT STABILITY
OVER ATP

SOURCE	ARC-SEC 3 σ
RANDOM VIBRATION	11
MEASUREMENT	3
FIXTURE/IRU REPEATIBILITY	10
RSS	15.2 ARC SEC
SPEC	35 ARC SEC

PRELIMINARY

IRU/ACA Stability

BOLLERCK

Components	1 Second (arcsec)	For 1 °F (arcsec)	ΔT	48 hr (arcsec)	EOL (arcsec)
AC Mount (1)				0.062	
AC Mount Align Plate (1)				0.101	
AC Mount Align Shim (1)				0.083	
AC Mount Bracket (1)				7.83	
AC Mount to HRMA IF Plane (2)				0.41	0.8
Total AC IF to HRMA IF				8.486	
IRU #1					
Radiator Plate/Mt (3)	0.00036	0.919	5	4.595	
E-Box Fittings (3)	0.000062	0.114	5	.57	
Forward Bulkhead (4)		0.773	5	3.865	
Strut Fittings (4)		0.586	5	2.93	
HRMA Strut to HRMA IF (4)		0.264	5	1.32	
Total IRU#1				13.28	
IRU #2					
E-Box Fittings (3)	0.0000665	0.122	5	.61	
IRU Bracket & Radiator (3)	0.000344	1.578	5	7.89	
Forward Bulkhead (4)		0.909	5	4.545	
Strut Fittings (4)		0.363	5	1.815	
HRMA Strut to HRMA IF (4)		0.264	5	1.32	
Total IRU#2				16.18	
Total IRU IF to HRMA IF					
RSS OBA & HRMA				18.27	

References:
1) AXAF-94-0231 Bedzyk
2) AXAF-94-0178 Thrasher
3) AXAF-95-0323 Gossard
4) AXAF-96-0002 Brown

Lee Harper
Nicolas Schwartz
310-722-1322
Grid 8

A II (4)

RSS THE LARGEST OF THESE WITH 8.486

A II (4)

IF

expected use gradient over 48 hours.

Check Optical Bench on IRU

Kodak Thermal group still need work out with TRW

Lee Harper TRW thermal

AXAF Comp Company? Nicolle Lynch

IRU - AXAF

probably better than indicated due to the limited capability of the rate table to come to a stop without overshooting position.

SCALE FACTOR STABILITY: EQ SPEC 3.2.3.5

AXAF - I SCALE FACTOR STABILITY
3 σ, 9.6 YEARS (5 YRS OPERATING, 4 YRS STORAGE, 5000 HRS GND OP)

GYRO and VFC TEMPERATURE CONTROLLED

PARAMETER	PPM (3 σ)	COMMENTS
IRU CALIBRATION	12.6	LOW RANGE
GYRO		
TEMPERATURE	12.0	ZODIAQUE ANALYSIS
RADIATION	2.4	ZODIAQUE ANALYSIS
CRYSTAL OSCILLATOR		
TIME	18.2	ZODIAQUE ANALYSIS
TEMPERATURE	32.1	ZODIAQUE ANALYSIS
POWER SUPPLY VARIATION	2.4	ZODIAQUE ANALYSIS
RADIATION	9.1	ZODIAQUE ANALYSIS
VFC		
TIME, TEMPERATURE, RADIATION	210 + MEAN OF 132	
GYRO STANDARD AGING	160.4	ZODIAQUE ANALYSIS
RSS	267.6 + MEAN OF 132	= 400 PPM
SPECIFICATION		400 PPM

determined

no way to bring these numbers down and the cal #

NOTE: THE VALUES TAKEN FROM THE ZODIAQUE ANALYSIS WERE ADJUSTED FOR THE DIFFERENCE IN TIME FOR AXAF-I AS √9.6 YEARS/14 YEARS.

3.2..3.7.1 ABSOLUTE VALUE (AIDR)

The maximum AIDR value of the five delivered Zodiaque IRUs was less than 2.3 deg/hr. The average was less than 1.16 deg/hr. The gyro specification for absolute AIDR is 5.5 deg/hr. The AXAF-I IRU requirement of less than 7 deg/hr will be easily met .

Milstar 10 yrs

√ OF DIFFERENCE

- Y258 R050 -

AI - VFC

A7 A75 A78

Details of S/F

MPS Spacecraft Function Processing

M. Newhouse

Computer Sciences Corporation **March 8, 1995**

Spacecraft Functions Supported

Commanding

- ***SIs: ACIS, HRC, LETG, HETG***
- ***PCAD: maneuver, AC, SAs***
- ***Communications: setup***

Operations

- ***Communications: LGA, SSR***
- ***Power: batteries***

Spacecraft Functions (1 of 2)

For science instruments, support activities for

- ***instrument warm-up***
- ***SIM positioning***
- ***grating positioning***
- ***inline operations***
- ***background operations***

For spacecraft maneuvers, support activities for

- ***target positioning***
- ***momentum dumping***
- ***sun avoidance***
- ***settling time***

Spacecraft Functions (2 of 2)

For AC acquisitions, support activities for

- ***star acquisition***
- ***attitude control***

For SAs, support activities for

- ***SA positioning***
- ***settling time***

For communications, support activities for

- ***configuring onboard communications hardware***
- ***reconfiguring onboard communications hardware***

Function Processing Control (1 of 4)

Resource compatibilities driven by database parameters

Resource compatibilities

- ***Incompatible operationally***
  - ***ACIS inline with HRC inline***
  - ***LETG with HETG***
  - ***LETG or HETG without ACIS or HRC***
  - ***maneuver (target or momentum management) under AC attitude control***
  - ***maneuver (target or momentum management) with AC acquisition***
  - ***solar array maneuver without spacecraft maneuver***
  - ***ACIS or HRC inline during SIM positioning***
  - ***ACIS background with HRC background (?)***

Function Processing Control (2 of 4)

Resource compatibilities

- ***Compatible operationally, but not schedulable***
  - ***ACIS or HRC inline and taking data during maneuver (target or momentum management)***
  - ***ACIS or HRC inline and taking data during AC acquisition***
  - ***ACIS or HRC inline during grating positioning***
- ***Compatible operationally, but preferred***
  - ***SSR playback during maneuver (target or momentum dump)***
  - ***uplink or downlink during maneuver (target or momentum dump)***

Function Processing Control (3 of 4)

Resource compatibilities

- ***Compatible and preferred scheduling***
  - ***ACIS warm-up and bias measurement during maneuver, occultation, or HRC inline***
  - ***HRC warm-up during maneuver, occultation, or ACIS inline***
- ***Compatible and required operationally***
  - ***either ACIS or HRC with LETG or HETG***
  - ***maneuver with solar array position***
  - ***uplink and downlink with SSR playback***
  - ***uplink and downlink with command link***
  - ***downlink with uplink***

Function Processing Control (4 of 4)

Resource compatibilities

- ***Compatible operationally, no restrictions on scheduling***
  - ***ACIS inline with HRC background***
  - ***HRC inline with ACIS background***
  - ***ACIS or HRC background with maneuver (target or momentum management)***
  - ***AC attitude control with any SI or grating***
  - ***SSR recording with any other spacecraft activities***
  - ***SSR playback, uplink, or downlink with any other spacecraft activity except maneuver (see above)***
  - ***momentum management maneuver with target maneuver***

Observation Activities (1 of 2)

Warm-up instrument

- ***scheduled based on previous instrument in use***
- ***duration from ODE spacecraft characteristics***

ACIS Bias (?)

- ***scheduled based on orbit event (radiation zone exit) or other TBD criteria***
- ***duration from ODE spacecraft characteristics***

Position SIM

- ***scheduled based on previous SIM position***
- ***duration calculated based on ODE spacecraft characteristics parameters***

Position grating

- ***scheduled based on previous grating position***
- ***duration from ODE spacecraft characteristics***

Observation Activities (2 of 2)

Maneuver spacecraft

- ***scheduled based on previous spacecraft attitude***
- ***duration calculated base on ODE spacecraft characteristics and constraints parameters***

Acquire guide stars

- ***scheduled based previous AC activity***
- ***duration from ODE spacecraft characteristics or calculated based on spacecraft characteristics parameters (?)***

Take data

- ***always scheduled***
- ***duration obtained from OR request (can be extended after all requests scheduled)***

Calibration Activities (1 of 2)

Warm-up instrument

- ***scheduled based on activity scenario and previous instrument in use***
- ***duration from ODE spacecraft characteristics***

ACIS Bias (?)

- ***scheduled based on activity scenario***
- ***duration from ODE spacecraft characteristics***

Maneuver spacecraft

- ***scheduled based on activity scenario and previous spacecraft attitude***
- ***duration calculated base on ODE spacecraft characteristics and constraints parameters***

Calibration Activities (2 of 2)

Acquire guide stars

- ***scheduled based on activity scenario***
- ***duration from ODE spacecraft characteristics or calculated based on spacecraft characteristics parameters (?)***

Take data

- ***scheduled based on activity scenario***
- ***duration obtained from OR request (can be extended after all requests scheduled)***

Activity Control

How should operations (FOT and SOT) control scheduling of activities associated with ORs and ERs?

- ***option 1 - rules override activity scenario; for example, activity scenario include instrument warm-up, but instrument warm-up is only performed in instrument not previously in use***
- ***option 2 - rules override default activity scenario, but including an activity scenario in the OR or ER ensures all activities performed, regardless of rules; for example, wish to perform bias measurement although previous observation used same observation mode***
- ***option 3 - other?***

Activity: Page _____ of _____ .

Observation Request/Engineering Request	Activity Description		Command Sequence Definition	OFLS	Timing

Activity: IRU Calibration Maneuvers

Observation Request/Engineering Request	Activity Description(S)	Timing	Command Sequence Definition	Timing
CAL, MANEUVER=(1.0,0.0,0.0,90.9), DURATION=(5M)	*NOM_OBS Activity Desctipion* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	T_1	*NOM_MAN Command Sequence* NOM_MAN, AOPCADMD,MODE=‘NMM’ AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE=‘Maneuver’ ???	T_1 T_1+1S T_1+2S
MANEUVER=(0.0,1.0,0.0,90.9), DURATION=(5M)	*NOM_OBS Activity Desctipion* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_2=T_1+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* NOM_MAN, AOPCADMD,MODE=‘NMM’ AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE=‘Maneuver’ ???	
MANEUVER=(0.0,0.0,1.0,90.9), DURATION=(5M)	*NOM_OBS Activity Desctipion* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* NOM_MAN, AOPCADMD,MODE=‘NMM’ AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE=‘Maneuver’ ???	

Activity: Observation without Aspect Stars

Observation Request/Engineering Request	Activity Description(S)	Timing	Command Sequence Definition	Timing
OBS, TARGET=(245.0,88.3), SI=ACIS-I, DURATION=(40000)	*NO_STAR Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,NASSTAR	 T_1	NOM_MAN, AOPCADMD,MODE=‘NMM’ AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3 AOSTRCAT,NUM_ENTRIES=0 AOATTCMD,MODE=‘Maneuver’ ???	 T_1 T_1+1S T_1+2S

Observation Request/Engineering Request	Activity Description(S)	Timing	Command Sequence Definition	Timing
OBS, TARGET=(10.0,20.0), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ... SCIOBS,SI	T_1	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ??? *NOM_SCI Command Sequence* ???	T_1 T_1+1S T_1+2S
			NOM_SCI Command Sequence ???	
TARGET =(10.2,20.0), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_2=T_1+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	
TARGET =(10.4,20.0), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	

TARGET =(10.6,20.0), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	
TARGET =(10.6,20.2), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	
TARGET =(10.4,20.2), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	

TARGET =(10.2,20.2), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	
TARGET =(10.0,20.2), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	
TARGET=(10.4,20.0), DURATION=(5M)	*NOM_OBS Activity Description* MANACQ, Q1,Q2,Q3 NAQSTAR,AQIM1,AQY1,AQZ1, AQMMAX1,AQMMIN1,AQBOX1, ...	$T_3=T_2+T_m+T_{aq}+5M$	*NOM_MAN Command Sequence* AOPCADMD,MODE='NMM' AOTRGREF,TQ1=Q1,TQ2=Q2, TQ3=Q3,IM_NUM=AQIM1, Y_ANGLE=AQY1,Z_ANGLE=AQZ1, MAX_MAG=AQMMAX1, MIN_MAG=AQMMIN1,... AOATTCMD,MODE='Maneuver' ???	