

## INTERACTIVE EXPERIMENTERS' PLANNING PROCEDURES AND MISSION CONTROL

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I want to describe a very promising approach to spacecraft and experiment operation planning, based on an interactive CRT system.

Planning for space astronomy operations begins in the space dimension (Figure 1). In this dimension we can identify spatial interrelationships among prospective targets and also prohibit constraint regions such as effective body sizes. This planning approach is satisfactory for static, long-term targeting. However, there are many more constraints besides occulting bodies, and most of these constraints are extremely dynamic, such as the motion of the earth, which may sweep through this picture many times a day. Therefore most constraints cannot be effectively represented in the space dimension.

The complexity of planning in the time dimension, however, becomes apparent when even a few constraints are included, as in Figure 2. The planner may have to take account of ground contacts, target occultation by the effective earth, and spacecraft night periods; also variations in background count due to trapped particle radiation. He must especially consider all the hardware interrelationships and restrictions internal to the experiment, or between experiments, or among all the experiments, the spacecraft, and the external constraints.

Previous approaches to planning were to provide the planner with computer-produced aids, then when he had devised an entire plan, to run it through the computer and check its validity against all the constraints and restrictions. Frequently this approach necessitated a number of reruns until these iterations converged to a valid plan. It should be stressed that these reruns were not always due to human error, but were frequently forced by the dynamic interrelatedness of many of the restrictions (i.e., the precise restrictions depend on the activity itself, and hence cannot be fully known until the plan is generated).

It was a strain with the previous planning procedures to run two times real-time on the OAO, due to the reruns, the time getting on and off the computer, and so on.

The planning system I want to describe today, called PROFILE, allows the planner to validate his plan interactively as it is being generated segment by segment, and thus eliminate those reruns. This system is in daily operational use by the University College of London experimenter on OAO-C. Using this system, he is routinely generating a 24-hour schedule in one hour of operator time, and less than four hours total elapsed staff time. This is six times real-time, which is a threefold improvement over forerunner systems.

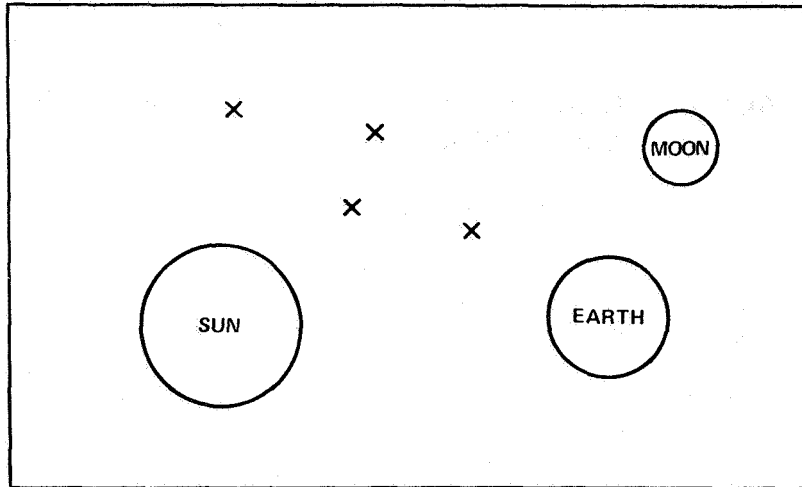


Figure 1. Experiment planning: the space dimension.

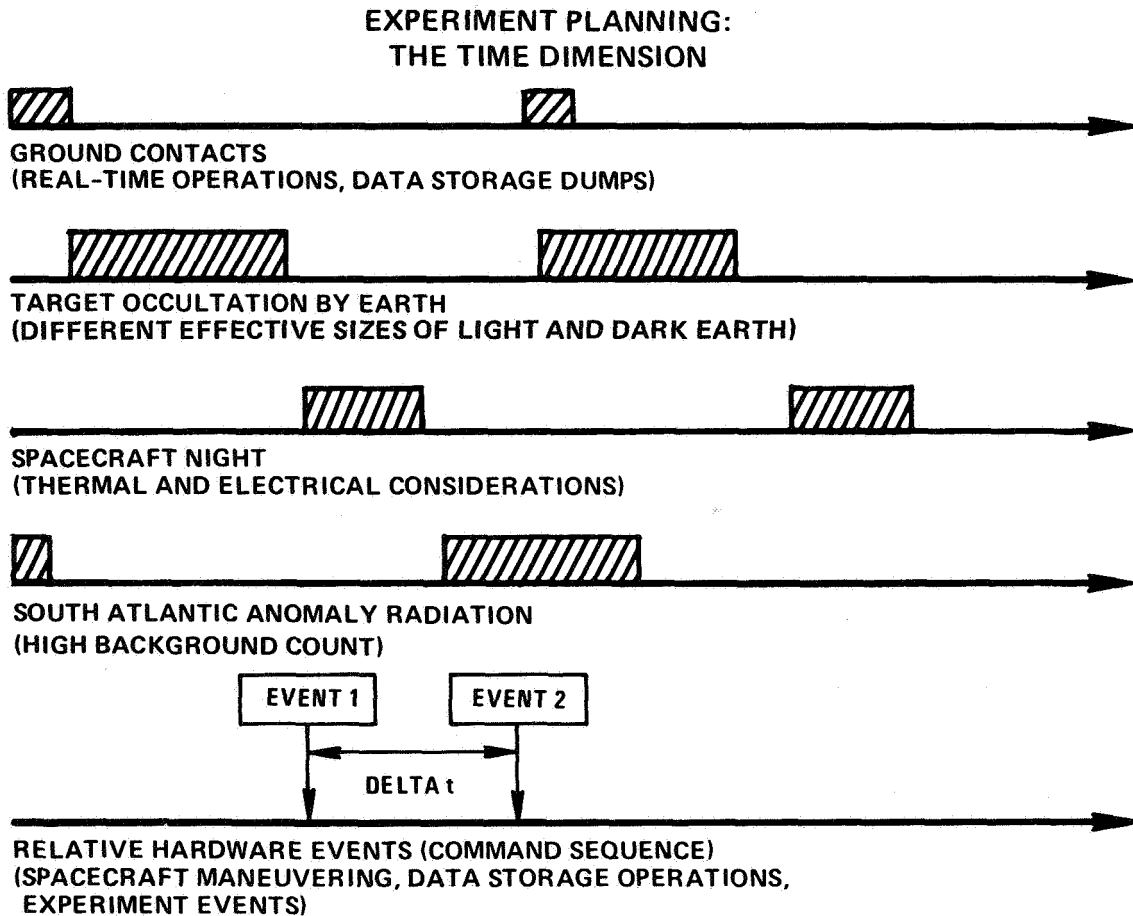


Figure 2. Experiment planning: the time dimension.

The planner at the CRT terminal brings up an initial display containing a blank time line initialized to the time interval of interest. Figure 3 is an actual photograph of the display to emphasize that this is a real system that is in use today. Unfortunately it is hard to read, so I have taken the liberty of having it transcribed to print. The time line shown in Figure 4 is GMT; the experimenter may work with a spacecraft clock time scale if he chooses. The Attitude Control Display area allows the planner to input times, spacecraft attitudes, and specific slew maneuvers if desired, as well as verbs to control the software system itself. The operator has all sorts of capability for shifting things up and down, left and right, for expanding and contracting the time scale, for manipulating things, copying things, and logging things to the printer.

In Figure 5 the experimenter has displayed some of his constraints on the time line. The ground contact shown is Rosman 982, and spacecraft sunrise occurs at approximately 7:17. The target at right ascension 4:39, declination 22:51, is unocculted by the earth until approximately 7:37.

Let us suppose that after examining these constraints, the planner decides that immediately after the contact he will perform a segment of activity involving the fine error sensor, then slew to a new target pointing.

First, he calls out the commands which perform his activity segment with the fine error sensor. You can see in Figure 6 the English language schedule being built up to describe the command sequence he is generating; on the time line, a representation (the interval of E's) that the fine error sensor is enabled, and the specific times (the T's) that events are called out in the command sequence. Let me point out that specific event times such as those shown may be entered into the schedule as needed, simply by pointing the light pen at the time mark of interest on the time line — a push of the light pen causes the appropriate time field to be entered into the schedule by the computer.

In Figure 7 the experimenter has entered a new desired target pointing into attitude 2, and the computer in turn has first computed the optimum roll angle to maximize solar paddle power, then has calculated the shortest slew maneuver which will take the spacecraft from attitude 1 to attitude 2. On the time line, the computer has displayed the slew and settle interval for the maneuver. The experimenter sees that following the maneuver he has only a minute or so before the target becomes occulted by the earth. Since this is not enough time to do anything useful, he shifts to the other end of the occultation interval to begin experimenting.

The Experiment Control Display is shown in Figure 8. The configuration or state of the UCL experiment is completely defined by the settings or values of 18 parameters, e.g., 3 sensitivity parameters, 2 pulse shape discriminator parameters, and so on. Configuration 1, the current configuration, is always given in the top row. Configuration 2, the desired configuration, is input by the experimenter to the second row; actually he need enter only parameter change values (“\*” means “stays the same”). The operator has a super-convenient way to enter change parameters to configuration 2; all he need do is point the light

pen at the parameter field he wants changed and the next parameter value in cyclic order will be entered by the computer. Thus a push of the pen at the first sensitivity parameter will set the configuration 2 value to "L" for "low"; the next push will set it back to "H". At "iris," consecutive pushes will set the change value to 3, then 4, then 1, then back to 2, and so on. In this way, a few quick strokes of the pen to set up the desired configuration 2, one stroke of the pen on the time line to enter into the specific time field the time at which he wants the indicated configuration change to occur. Three things happen: The command sequence which effects the configuration change is computed and entered on the schedule (Figure 9). The current configuration is automatically updated on the display to the new configuration and a T is marked on the time line, indicating the time of the change to the current configuration. The system is now ready to respond to the next configuration change desired.

Figure 10 shows the last display in the original form to highlight the fact that the planning system shown here is not only a design, but is in daily operational use. It represents a significant technological advance over its predecessors. It is very responsive, very flexible, easy to add new capability to; in a quick-turnaround situation, it is unexcelled. I feel confident in predicting that many of the features which exist on this system today will find their way into spacecraft and mission control systems of the future.

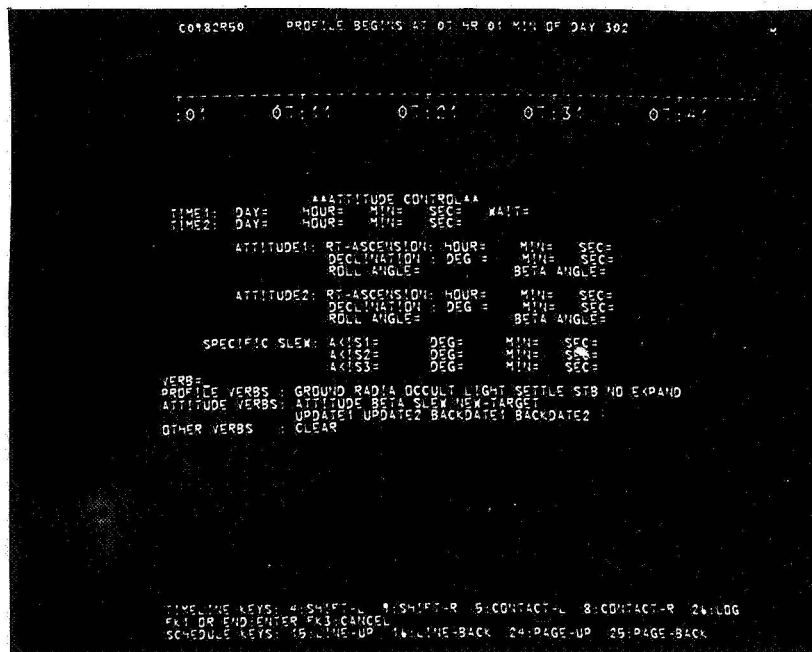


Figure 3. Actual photograph of CRT Display 1.

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C0982R50      PROFILE BEGINS AT 07 HR 01 MIN OF DAY 302      M
+-----+-----+-----+-----+
:01          07:11          07:21          07:31          07:41

**ATTITUDE CONTROL**
TIME 1:  DAY =   HOUR =   MIN =   SEC =   WAIT =
TIME 2:  DAY =   HOUR =   MIN =   SEC =

ATTITUDE 1:  RT-ASCENSION:  HOUR =   MIN =   SEC =
              DECLINATION:  DEG =   MIN =   SEC =
              ROLL ANGLE =          BETA ANGLE =

ATTITUDE 2:  RT-ASCENSION:  HOUR =   MIN =   SEC =
              DECLINATION:  DEG =   MIN =   SEC =
              ROLL ANGLE =          BETA ANGLE =

SPECIFIC SLEW:  AXIS 1 =          DEG =   MIN =   SEC =
                AXIS 2 =          DEG =   MIN =   SEC =
                AXIS 3 =          DEG =   MIN =   SEC =

VERB =
PROFILE VERBS :  GROUND RADIA OCCULT LIGHT SETTLE STB NO EXPAND
ATTITUDE VERBS:  ATTITUDE BETA SLEW NEW-TARGET
                  UPDATE 1 UPDATE 2 BACKDATE 1 BACKDATE 2
OTHER VERBS:    CLEAR

TIMELINE KEYS:  4: SHIFT-L  9: SHIFT-R  5: CONTACT-L  8: CONTACT-R  26: LOG
FK1 OR END:  ENTER FK3: CANCEL
SCHEDULE KEYS:  15: LINE-UP  16: LINE-BACK  24: PAGE-UP  25: PAGE-BACK

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Figure 4. Artist's description of CRT Display 1.

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C0982R50      PROFILE BEGINS AT 07 HR 01 MIN OF DAY 302      M
GR R R R R R R R 0 9 8 2      G
O                               O O O O O O O O O O
+-----+-----+-----+-----+
:01          07:11          07:21          07:31          07:41
N N N N N N N N N N N N N N N N      P
RIGHT ASC = 4 39 14.44, DEC = 22 51 46.0

**ATTITUDE CONTROL**
TIME 1:  DAY = 302  HOUR = 7 MIN = 0  SEC = 52  WAIT =
TIME 2:  DAY =   HOUR =   MIN =   SEC =

ATTITUDE 1:  RT-ASCENSION:  HOUR = 4  MIN = 39  SEC = 14.44
              DECLINATION:  DEG = 22  MIN = 51  SEC = 46.0
              ROLL ANGLE =          BETA ANGLE =

ATTITUDE 2:  RT-ASCENSION:  HOUR =   MIN =   SEC =
              DECLINATION:  DEG =   MIN =   SEC =
              ROLL ANGLE =          BETA ANGLE =

SPECIFIC SLEW:  AXIS 1 =          DEG =   MIN =   SEC =
                AXIS 2 =          DEG =   MIN =   SEC =
                AXIS 3 =          DEG =   MIN =   SEC =

VERB =
PROFILE VERBS :  GROUND RADIA OCCULT LIGHT SETTLE STB NO EXPAND
ATTITUDE VERBS:  ATTITUDE BETA SLEW NEW-TARGET
                  UPDATE 1 UPDATE 2 BACKDATE 1 BACKDATE 2
OTHER VERBS:    CLEAR

TIMELINE KEYS:  4: SHIFT-L  9: SHIFT-R  5: CONTACT-L  8: CONTACT-R  26: LOG
FK 1 OR END:  ENTER FK 3: CANCEL
SCHEDULE KEYS:  15: LINE-UP  16: LINE-BACK  24: PAGE-UP  25: PAGE-BACK

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Figure 5. CRT Display 2.

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C0982R50      PROFILE BEGINS AT 07 HR 01 MIN OF DAY 302      M
GRRRRRRRRR0982      G
O      EEEEEEEEEEE      OOOOOOOOOOO
+-----+-----+-----+-----+-----+-----+-----+-----+
:01      07:11      07:21      07:31      07:41
NNNNNNNNNNNNNNNNNNNN      N
RIGHT ASC = 4 39 14.44, DEC = 22 51 46.0

ENTER ONE OF THE FOLLOWING:
RECORD GENERATION VERBS: N D H F V C T E S M *
RECORD MODIFICATION VERBS: INSERT REPLACE DELETE
OTHER VERBS: CONTROL UCL COPY ENDCOPY

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00010 N 00982 R 302 07 01 28
00020 HOLD ATTITUDE 9
00030 E 302 07 14 302 07 24
00040 C PEP, 1HLA, 2SLA, 2SPA, SRRA, ENDC
00050 T 302 07 14
00060 HOLD ATTITUDE E
00070 T 302 07 19
00080 C PEP, 1SLA, 1HLA, 2HLA, ENDC
00090 T 302 07 24

```

TIMELINE KEYS: 4: SHIFT-L 9: SHIFT-R 5: CONTACT-L 8: CONTACT-R 26: LOG  
END OR 1: ENTER 6: RE-INIT 31: RETURN 22: CANCEL-ALL 3: CANCEL VERB  
SCHEDULE KEYS: 15: LINE-UP 16: LINE-BACK 24: PAGE-UP 25: PAGE-BACK

Figure 6. CRT Display 3.

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C0982R50      PROFILE BEGINS AT 07 HR 01 MIN OF DAY 302      M
GRRRRRRRRR0982      G
O      EEEEEEEEEEE      OOOOOOOOOOO
+-----+-----+-----+-----+-----+-----+-----+-----+
:01      07:11      07:21      07:31      07:41
NNNNNNNNNNNNNNNNNNNN      N
*
RIGHT ASC = 4 39 14.44, DEC = 22 51 46.0

**ATTITUDE CONTROL**
TIME 1: DAY = 302 HOUR = 7 MIN = 24 SEC = 59 WAIT =
TIME 2: DAY = 302 HOUR = 7 MIN = 36 SEC = 15

ATTITUDE 1: RT-ASCENSION: HOUR = 4 MIN = 40 SEC = 38.46
DECLINATION: DEG = 22 MIN = 54 SEC = 29.4
ROLL ANGLE = 143.85231 BETA ANGLE = 36.486958

ATTITUDE 2: RT-ASCENSION: HOUR = 5 MIN = 32 SEC = 54.92
DECLINATION: DEG = 22 MIN = 0 SEC = 6.6
ROLL ANGLE = 136.67832 BETA ANGLE = 48.436237

SPECIFIC SLEW: AXIS 1 = ROLL DEG = -2 MIN = 47 SEC = 00.0
AXIS 2 = YAW DEG = -9 MIN = 41 SEC = 31.0
AXIS 3 = PITCH DEG = 7 MIN = 17 SEC = 3.1

VERB =
PROFILE VERBS: GROUND RADIA OCCULT LIGHT SETTLE STB NO EXPAND
ATTITUDE VERBS: ATTITUDE BETA SLEW NEW-TARGET
UPDATE 1 UPDATE 2 BACKDATE 1 BACKDATE 2
OTHER VERBS: CLEAR
TIMELINE KEYS: 4: SHIFT-L 9: SHIFT-R 5: CONTACT-L 8: CONTACT-R 26: LOG
FK 1 OR END: ENTER FK 3: CANCEL
SCHEDULE KEYS: 15: LINE-UP 16: LINE-BACK 24: PAGE-UP 25: PAGE-BACK

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Figure 7. CRT Display 4.



