Astrophysical Phenomena Revealed by Space VLBI
H. Hirabayashi, P.G. Edwards and D.W. Murphy (eds.)

HALCA's Operating Efficiency & Lifetime

Y. MURATA[1] & THE HALCA OPERATION GROUP[1,2]

[1] *ISAS, Yoshinodai 3-1-1, Sagamihara, Kanagawa 229-8510, Japan*
[2] *NAO, Ohsawa 2-21-1, Mitaka, Tokyo 181-8588, Japan*

Abstract

We describe the current status of HALCA and the future prospects of the mission. HALCA must be operated in a three-reaction wheel mode from the middle of October 1999, affecting the operating efficiency of HALCA. The mission lifetime may exceed 5 years, if there are no unexpected problems.

1 HALCA History and Status

We have operated HALCA (Hirabayashi et al. 1998) for about 3 years, undertaking General Observing Time (GOT) observations from 13 July 1997. About 510 observations have been made, of which roughly 340 are GOT observations, 130 are Survey Program observations, and 40 are test observations.

On several occasions HALCA has stopped observing for an extended period, sometimes due to trouble with the on-board system. One such problem is the hanging-up of the on-board telemetry. We experienced this problem for the first time on 31 August 1998. It took about 2 months to recover, which was required for understanding the problem and establishing the recovery plan. We had the same trouble on 16 November 1998, 22 February 1999, and 16 November 1999. Each time we succeeded in recovering with a shorter down-time than previously. Another problem is that one of the four reaction wheels was broken on 7 October 1999, resulting in the loss of the attitude control for about 2 weeks. We could not move to the safe-hold mode due to the lack of the thruster fuel required for safe-hold maneuvers. After recovering from this accident, observing re-started in December 1999, however HALCA lost attitude control again toward the end of December, and was in free-spin mode at a time of the symposium.

2 Recovery Plan/Operation

We had to wait for a number of conditions to be met for recovery: the thermal condition of the reaction wheels and the batteries and also the angular momentum of the satellite. The angular momentum has to be compensated by the three reaction wheels. Finally we also needed to care about the satellite's sun angle after recovery, with a sun angle of 180° (the sun is located toward the $-z$ direction, or bottom of the satellite) desired. Recovery efforts started in the week following the symposium because we found the HALCA conditions were good. We successfully regained attitude control on 5 February 2000. We started Ku tracking from February 15, and are, at the time of writing, preparing to start the observation starting from the beginning of March. We have the apogee eclipse "season", during which eclipses last about 90 minutes, from April 12 to May 9, after which HALCA enters a "no eclipse" season again. The decision on when to change the attitude of HALCA, e.g. from sun angles near $\sim 180^\circ$ to those near 90°, will be made at this time.

3 Operation Efficiency with Three Reaction Wheels

We need at least three reaction wheels to have 3-axis control of the satellite's attitude. However, the four reaction wheels of HALCA were symmetrically located, and were designed so that the total angular momentum of the satellite was zero. Thus there was no need to worry about the intrinsic angular momentum of HALCA when we had four reaction wheels for attitude control. However, it is impossible to have zero-momentum attitude control with three reaction wheels, and we must switch to biased-momentum control. This means the rotation speed of each reaction wheel after the maneuver is different from that before the maneuver. Large maneuvers may make the rotation speeds of the wheels exceed their limits. Allowed maneuvers are now typically 10°–30°, depending on the exact conditions of the maneuver.

During the perigee passage after a maneuver the accumulated angular momentum is dumped by the magnetic torquer, restoring the reaction wheel rotation speeds to their nominal values. It would be possible therefore to make a maneuver every orbit, if the magnetic torquer worked perfectly. However, we need to study how the reaction wheel rotation speeds changed in real operations. It seems that one maneuver per two orbits is the optimistic view, and that having to check the rotation speeds before every maneuver during a Kagoshima commanding pass is the pessimistic view.

The total capacity for momentum accumulation from external perturbations has become smaller in three reaction wheel mode. The main

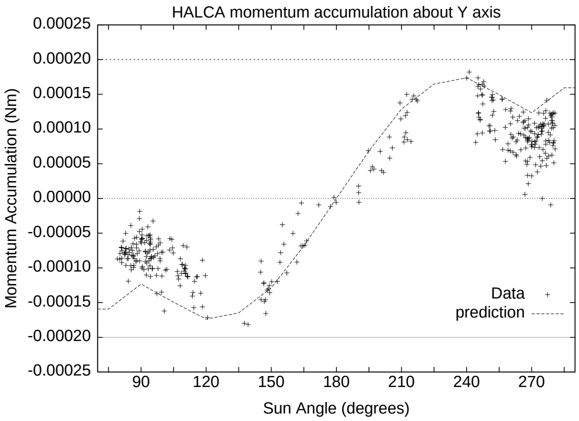

Figure 1: The torque around the y axis of HALCA versus the sun angle measured from HALCA's $+z$ axis. The "+" signs are the measured data, and dashed lines show the expectation from a simple model.

external force is solar ram pressure. Figure 1 shows the torque due to solar ram pressure versus sun angle (measured from the HALCA $+z$ axis). It is difficult to maintain HALCA's attitude when perturbations exceed the momentum accumulation of about 0.0001 Nm per orbit, which comes from the capacity of the reaction wheels. So only the solution is attitudes with sun angles of 165°–195°. But this situation reduces the science which can be done, because we can only observe sources in the anti-sun direction, and there is a large area of sky which cannot be observed with this attitude. So we are now studying the possibility that HALCA observes in the sun angle range 260°–280°, which has a larger sky coverage than that of 165°–195°. We can offset the range of the momentum accumulation from ±0.0001 Nm to 0.0–0.0002 Nm, for example, by changing the parameters of the momentum dumping with the magnetic torquer. It seems that the sun angles of 80°–100° is another solution, but we have more experience in the 260°–280° range than at 80°–100°. We need to get more data and study it carefully.

Because of the maneuver limitations, it is difficult to make a large attitude change in one day. We must pick sources close to the previous source. If we must monitor the rotation speed of the reaction wheels, it will take 2–3 days to maneuver to the next source, and so the efficiency of maneuvering is reduced. Multi-frequency observations of the same source, e.g. 1.6 GHz on one day and 5.0 GHz the next, increase the observing efficiency.

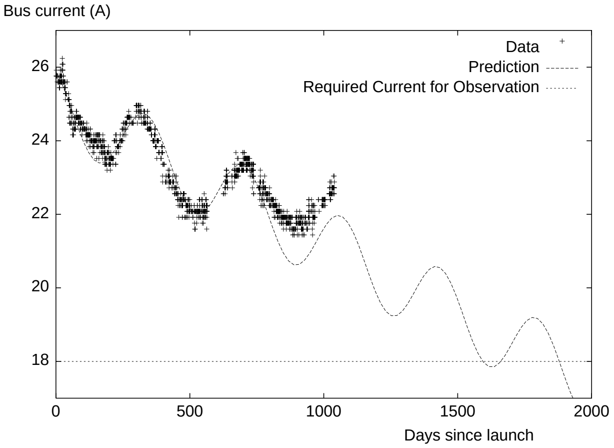

Figure 2: The time from launch in days and the output from the solar battery measured as the bus current. The required current for observing is more than 18 A. The plotted curve assumes the degradation is linear.

4 What Will Decide HALCA's Life-Time?

It was originally thought that the solar panel degradation would limit the HALCA's life-time to 3–5 years. However, current data for the degradation indicates that we can observe for more than 5 years (Figure 2). We now think the solar panels might not decide the life time of HALCA. The thruster fuel is nearly finished and so we will not use the thrusters in normal operations. The thrusters were not used in the last two recovery operations, and so this also might not limit HALCA's life-time, however the lack of thrusters does make recovery operations riskier, and so may have an effect on HALCA's life-time. Perhaps the most likely problem is the failure of on-board instrumentation. We have already experienced problems with the reaction wheels and the data handling unit. Most of the components were designed assuming a 3–5 year life-time, however HALCA's repeated system shutdowns and re-starts have probably stressed some components, reducing their life-time.

Acknowledgements. We gratefully acknowledge the participants of the symposium. The good results of the VSOP observations encourage us very much.

References

Hirabayashi, H., Hirosawa, H., Kobayashi, H. et al. 1998, *Science*, **281**, 1825 and erratum **282**, 1995