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Launch and Early Orbit Phase Simulations by using the KOMPSAT Simulator

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Abstract

The KOMPSAT, which is scheduled to be launched by Taurus launch vehicle in late November of 1999, will be in a sun-synchronous orbit with an altitude of 685km, eccentricity of 0.001, inclination of 98deg and local time of ascending node of 10:50 a.m.

Electronics and Telecommunications Research Institute and Daewoo Heavy Industry had jointly developed a KOMPSAT Simulator as a component of the KOMPSAT Mission Control Element. The MCE had been delivered to Korea Aerospace Research Institute for the KOMPSAT ground operation. It is being used for training of KOMPSAT ground station personnel. Each of satellite subsystems and space environment were mathematically modeled in the simulator. To verify the overall function of KOMPSAT simulator, a Launch and Early Orbit Phase(LEOP) operation simulations have been performed. The simulator had been verified through various tests such as functional level test, subsystem test, interface test, system test, and acceptance test. In this paper, simulation results for LEOP operations to verify flight software adapted into simulator, satellite subsystem models and environment models are presented.

1. Introduction

British AeroSpace developed Eurostar Simulator for the geostationary communication satellite[1]. DFVLR/GSOC developed the low earth orbit spacecraft simulator for the ROSAT, so called AMCS (Attitude Measure and Control Subsystem) simulator, which is mainly for AOCS simulation[2]. Italian Space Agency developed a geosynchronous satellite simulator, called the ITAFSIM (ITALSAT AOCS Flight Simulator), which is also used mainly for simulation of AOCS [3]. ETRI developed Advanced Real-Time Satellite Simulator(ARTSS) for KOREASAT-1 as a laboratory model[4].

The KOMPSAT SIM is a comprehensive application software which includes satellite subsystem mathematical models for the KOMPSAT. Major functions of the SIM are the validation of command, functional validation and operation check of the Satellite Operation Subsystem(SOS), training of the KOMPSAT operators, anomaly analysis support, functional validation of the on-board flight software, and validation of spacecraft control laws and mission scenario, etc.

The KOMPSAT simulator, namely the SIM, provides real-time simulation capabilities for AOCS, EPS, TC&R, Ground Antenna Ranging & Tracking, Telecommand and Telemtry Processing, and comprehensive visualization tool for the satellite dynamics.

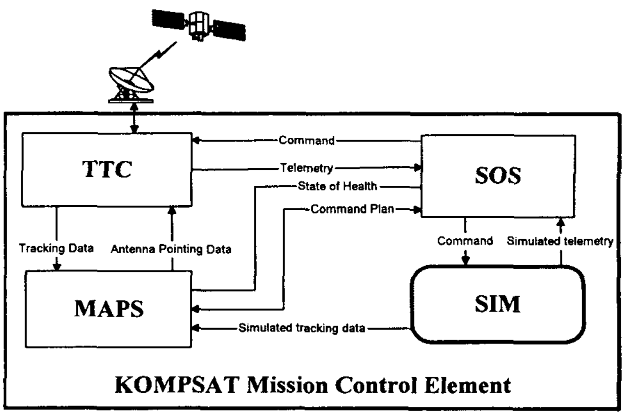

Fig. 1 : Schematics of the KOMPSAT MCE

2. SIM S

2.1 H/W Structure

Figure 2 shows the SIM H/W structure. The SIM main computer is the HPJ210 workstation which communicates with the other MCE subsystem, i.e. SOS and MAPS using the TCP/IP protocol via MCE LAN. The SIM also utilizes a pentium PC for VR graphic display of the KOMPSAT attitude and orbit motion. Two printers are used for printing out the simulation results including screen captured images.

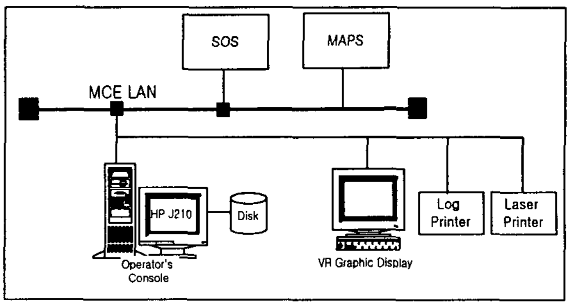

Fig. 2 SIM H/W Configurations

2.2 S/W Structure

The SIM consists of eight blocks such as MMI, Kernel, TC&R, EPS, Flight Dynamics, AOCS, Propulsion and Ground Simulation. These blocks are grouped or divided as tasks in order to make them as one of execution units of the SIM.

Under blocks, there are units containing mainly models of the spacecraft subsystem. MMI block handles command input, telemetry display, spacecraft trend and status display, etc.
Kernel block processes telecommand and telemetry, schedules the tasks in real time, and controls the simulation mode. Telecommand received from the kernel block, and corresponding telemetry generated from spacecraft models are processed in CCSDS format at the TC&R block. EPS block contains models for the simulation of power generation, battery status, and power system control unit. Blocks such as Flight Dynamics, AOCS and Propulsion are grouped as the sim_sdc task, which includes models for KOMPSAT orbit and attitude dynamics, sensors, actuators, and RDU. Ground simulation block contains models for tracking and ranging capabilities of the ground antenna. On board flight software(OBC, RDU, RDU) and control logic inside(acs and epd) are merged into TC&R, AOCS, and EPS blocks in SIM, respectively. Detailed implementation description is available in reference 5.

3. LEOP Operations

LEOP is a terminology for the launch and ascent, deployment, sun acquisition, earth acquisition, orbit maneuver check out phase and hand over of the KOMPSAT satellite for nominal mission operations[6].

3.1 Launch and Separation

KOMPSAT will be launched using Taurus launch vehicle from Vandenberg Air Force Base. Separation is initiated by launch vehicle and occurs at 00:15:00 after lift off over the a south of equator. At this moment tip-off rate should be less than two degrees per second with respect to all axes.

3.2 Solar Array Deployment

A breakwire indicator provides signal to the three spacecraft processors to "wake up" the processors which were held in reset mode during the launch state at satellite separation from the launch vehicle. The OBC will initiate relative time command sequences(RTCS) which will power up the required equipment for solar array deployment and attitude stabilization. The RTCS proceeds solar array deployment with out any help from the ground station. Consecutively, solar array deployment test is performed by checking satellite rate changes due to thruster firings. If solar arrays are not deployed, the redundant deployment device is initiated for the deployment.

3.3 Sun Acquisition

After the solar array deployment, the spacecraft will perform sun acquisition to satellite in a stable sun-pointed attitude. In other words, the satellite will point positive roll axis toward the sun from any starting attitude in sunlight. During eclipse, satellite maintains inertially fixed attitude by integrated gyro signals.

3.4 Earth Acquisition

The earth search is the maneuver of the satellite from sun pointing, two-axis control, to nadir pointing three-axis local-vertical, local-horizontal control. The satellite will await ground contact for earth contact for earth acquisition after sun acquisition. The earth acquisition is initiated by ground station via absolute time command. The maneuver will nominally be executed at 6:00 pm LST (north pole) or 6am LST(south pole). The satellite will rotate with respect to the yaw direction(sun direction) by thruster firings. When a zero crossing is observed by th Conical Earth Sensor(CES) in the roll error, the AOCS mode automatically transitions to attitude hold mode. The attitude hold mode will then maintain the spacecraft nadir pointed with a Local Vertical, Local Horizontal(LVLH) attitude.

3.5 Orbit Maneuvers

The Delta V calibration burn has to proceed after attitude hold mode is being worked correctly. It does not affect to the nominal orbit. Based on the launch vehicle insertion vector and tracking data, the post insertion orbit should be propagated throughout the LEOP period. Several times of orbit determination determine whether orbit correction maneuver are required or not. If it is required, MAPS produces proper orbit maneuvers and proper times. There are two type of orbit correction maneuvers. The one is in-plane maneuver which corrects orbit size or eccentricity vector and the other is out of plane maneuver which corrects local time and inclination. In this paper, in-plane delta V maneuver for orbit size correction is presented.

3.6 Science Mode Operation

Initial checkout of AOCS hardware units including in GPS should be proceeded prior to entering science mode. Satellite stays in science mode most of its lifetime. In this mode, spacecraft attitude is controlled by reaction wheel via conical earth sensor signals. Pointing accuracy of KOMSAT on specifications are satisfied; pointing error $\leq$ 0.1deg for roll, $\leq$ 0.18deg for pitch, $\leq$ 0.5deg for yaw w.r.t LVLH.

4. Simulation Results

KOMPSAT simulator has been validated through simulation of LEOP events such as sun acquisition after solar array deployment, earth acquisition, orbit raising maneuver(delta V burn), and entering science mode from attitude hold mode.

Table 1. presents initial setup data at spacecraft injection from launch vehicle. Initial body rates are given intentionally less than two degrees per seconds.

Table 1. Initial Simulation Conditions at (1999/11/03 7:28:00)

Orbit Data		Attitude Data	
Orbit Elements	Values	Euler Angle/Rate	Values
A(km)	7072.4232	Roll(deg.)	8.140
e	0.00160137	Pitch(deg.)	90.0
I(deg.)	98.12	Yaw(deg.)	0.0
Ω(deg.)	81.415	Wx(deg./sec)	1.5
ω(deg.)	179.996	Wy(deg./sec)	1.0
f(deg.)	0.006	Wz(deg./sec)	0.5

Figure 3 shows typical ground view of KOMPSAT during LEOP. Yellow area on the figure represents field of view from Korean Ground Station(KGS) which is located in Taejon.

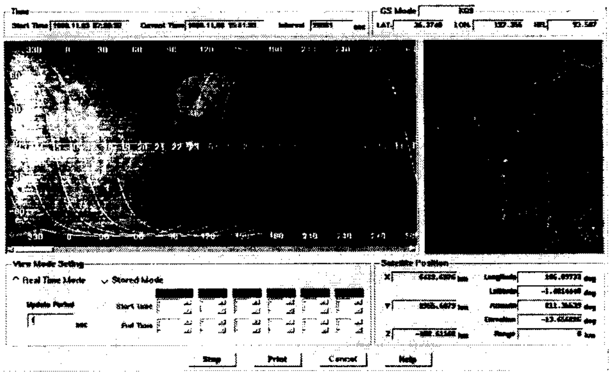

Fig. 3 : A Ground Track View of LEOP

After solar array deployment, spacecraft is in sun point mode. If it is in eclipse, it maintains its attitude inertially fixed via gyro signal. When it enters sunlight, the X- axis of the spacecraft towards the sun using thruster firing control. Figure 4 shows that body rates are died down and x-component of sun unit vector in body fixed coordinates goes to one and the others go to zero as sunlight comes up.

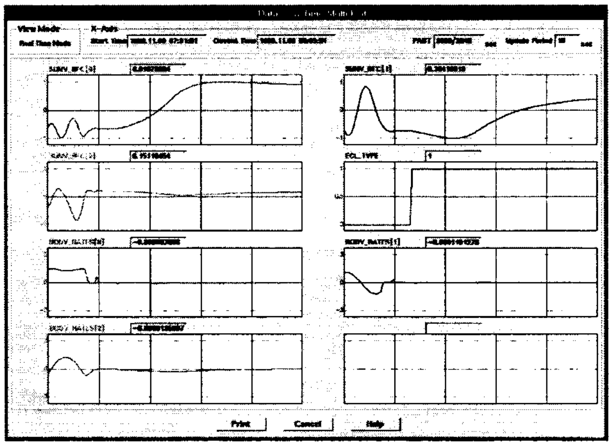

Fig. 4 : Time History of Sun Unit Vector, Body Rates, and Eclipse Type for Sun Point Mode from Injection.

Time histories of Euler angles and their rates w.r.t. the LVLH and solar array angles during earth search maneuver are presented in Fig. 5. Those values changes drastically during the maneuver. Then, Euler angles and rates are stabilized and solar array angles are steadily increased after the maneuver.

Similar behaviors on telemetry data for roll error, pitch error, roll rate, and pitch rate are shown in Fig. 6. The telemetry data for them is not available before the earth search maneuver because the corresponding sensor like conical earth sensor is not turned on. Body rates should be less than two degree per seconds during the earth search and they are satisfied in this simulation.

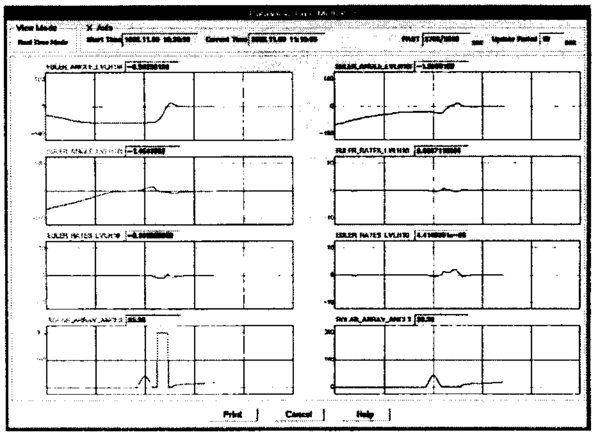

Fig. 5 : Time History of Euler angles and their rates w.r.t. the LVLH and Solar Array Angles during Earth Search Maneuver.

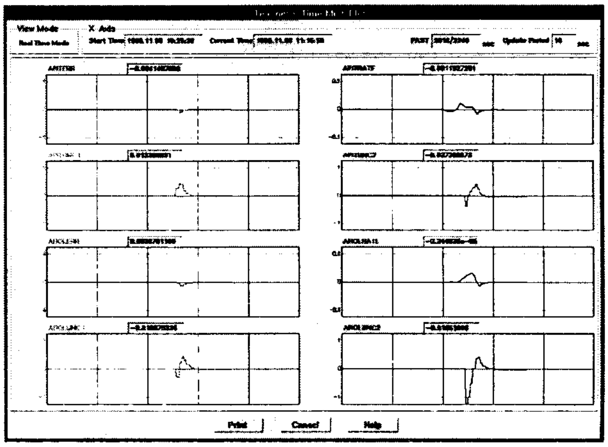

Fig. 6 : Time History of pitch error, pitch rate, roll error, and roll rate during Earth Search Maneuver

Several times of orbit determination decides whether the orbit correction maneuvers are required or not. If it has to be done, in-plane or out of plane maneuver is carried out. In this paper, only orbit rasing maneuver is considered. Table 2 summarizes the orbit maneuver characteristics.

Table 2. Orbit Maneuver Summery

Parameters	Values
Target	Orbit Raising 9.7 km
Burn Start Time	1999/11/14 1:30:47
Burn Duration Time(sec)	168.2
Delta V(m/sec)	5.11121

In Table 3, orbit raising maneuver results by SIM are closed enough to those predicted by MAPS[7]. Differences between them may be caused by several factors such as orbit propagation model, thruster characteristics, thruster firing logic attitude error effects, effective area, and so on.

Table 3. Final Orbit Elements at Epoch(1999/11/14 1:35:00)

Orbit Elements	MAPS	SIM
1. Semi-Major Axis(km)	7070.332	7070.701499
2. Eccentricity	0.0010687	0.001000
3. Inclination(deg.)	98.1249	98.127649
4. Long. of Asc. Node(deg.)	214.13193	214.130311
5. Agrument of Prigee(deg.)	162.46827	161.090010
6. True Nanomaly(deg.)	177.876511	179.255646
5+ 6	340.3448	340.3456

Figure 7 shows that time histories of Euler angles and rates and solar array angles have transient motion as spacecraft enters into science mode.

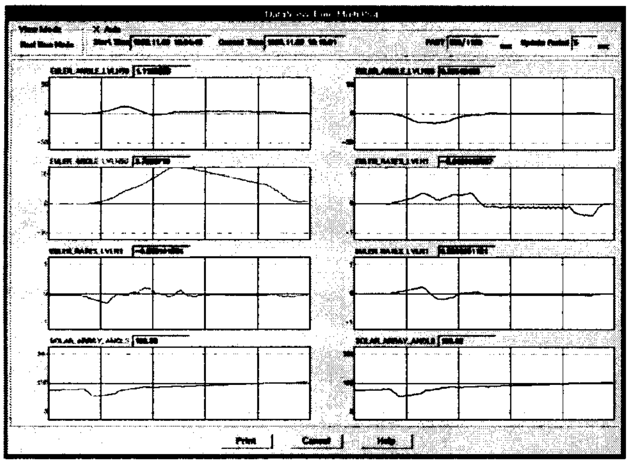

Fig. 7 Euler Angle referenced to LVLH in case of Normal Science Mode

Transient motion on telemetry for pitch and roll error, pitch and roll rate are shown in Fig. 8. Also, reaction wheel speeds in terms of tachometer telemetry are increased in magnitude and those rotating directions of 1 and 3 are opposite to 2 and 4. Several hundreds of seconds later, Euler angles are satisfied the pointing requirements for the science mode via magnetic torquer and reaction wheel controls.

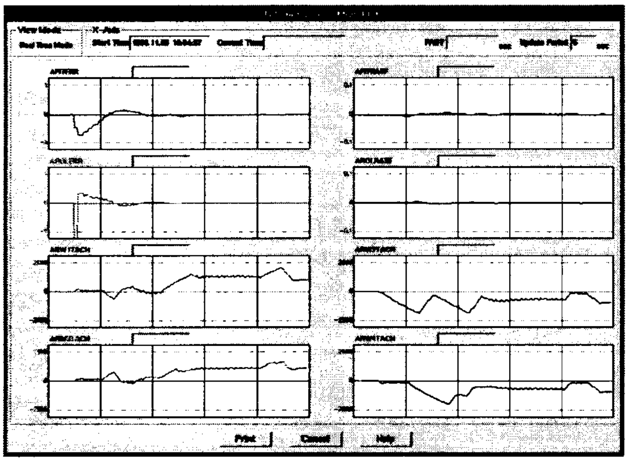

Fig. 8 : Body rates in Normal Science Mode

5. Conclusions

Simulations for LEOP operations of KOMPSAT using KOMSAT real-time simulator have been presented. Each event of LEOP operations can be simulated by SIM and those results are satisfied requirements on the specification. Result of orbit raising maneuver was comparable to the prediction of MAPS. On board flight software which merged into SIM cooperates well with SIM models. More detailed operation scenario or sequence of events for LEOP operation will allow more sophisticated simulation.

References

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[2] DFVLR/GSOC, *User Manual, ROSAT AMCS Simulator*, , March 1992

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[7] Byoung-Sun Lee, et. al. "Orbit Determination and Maneuver Planning for the KOMPSAT Spacecraft an Launch and Early Orbit Phase Operation," proceeding of the KAAC, Yongin, Korea, Oct., 1999.