HIGH FIDELITY MODELING AND SIMULATION OF A SATELLITE SYSTEM

Sungki Cho
Communications Satellite Development Center, ETRI
Gajung-dong 161, Yusong-gu, Taejon 305-350, Korea

Sanguk Lee
Communications Satellite Development Center, ETRI
Gajung-dong 161, Yusong-gu, Taejon 305-350, Korea

Jae Hoon Kim
Communications Satellite Development Center, ETRI
Gajung-dong 161, Yusong-gu, Taejon 305-350, Korea

Seong-Pal Lee
Communications Satellite Development Center, ETRI
Gajung-dong 161, Yusong-gu, Taejon 305-350, Korea

ABSTRACT

A method for modeling and simulation of a satellite system is presented. The characteristics of a typical satellite system is discussed. For high fidelity modeling and simulator development of a satellite, the object-oriented analysis and design methodology is discussed and applied.

1 INTRODUCTION

Electronics and Telecommunication Research Institute(ETRI) has been successfully developed KOREASAT Simulator, Advanced Real-Time Satellite Simulator(ARTSS)[1], and KOMPSAT-1(KOrean Multi-Purpose SATellite-1) Simulator[2]. Currently ETRI is developing simulator for KOMPSAT-2(KOrean Multi-Purpose SATellite-2) [3] which is scheduled to launch in 2004.

A satellite simulator is a tool used for verification of satellite operation, operator training, verification of flight software, and satellite's attitude and orbit motion analysis, and anomaly resolution support[2].

Some concerns are required to consider for the development of satellite simulator: Hardware system modeling method, flight software simulation, selection of simulator platform, design methodology, and etc. Since a software only simulator has a limitation in modeling hardware of the target system, a hardware in the loop(HIL) simulator[4] are frequently used to achieve required performances. Flight software simulation is critical for simulation of satellite operations [5-7]. The selection of the simulator platform is important for simulation performance and reliability. Simulator design methodology is critical specially for a satellite which is composed of very complicate subsystems in order to establish a efficient development environment.

In this paper, we focus on the method of modeling and design of high fidelity software simulator that provides most of the satellite functions and tools for supporting satellite operation and analyses.

Modeling process and design of spacecraft simulator are based on the object-oriented analysis and design (OOA/OOD) methodology.

2 SATELLITE SYSTEM

Satellite system is composed of several subsystems that contain different characteristics. Figure 1 shows KOMPSAT-2 satellite as an example of typical satellite system. A satellite system consists of spacecraft bus and solar arrays, hardware subsystem, on-board computer, and payload. A spacecraft bus is a structure on which all the satellite subsystems are attached. Solar arrays are normally panel type structures for electrical power generation and those are attached on the spacecraft main bus. Hardware subsystems are generally composed of an attitude and orbit control system(AOCS), an electrical power subsystem(EPS), and a telemetry, command, and ranging subsystem(TCR)[2]. AOCS subsystem includes actuators and sensors for satellite operation and control of a satellite. EPS subsystem has battery, Thermal control system, Solar array regulator, Power control unit, etc. TCR is composed of transmitter, receiver, and etc. Normally satellite system has one or more on-board processor for satellite operation, data management, and control. The on-board processor contains a specific software generally called flight software(FSW). Payloads are devices that perform specific functions for satellite mission objectives. Payload is usually camera, special sensor, telecommunication device, or etc.

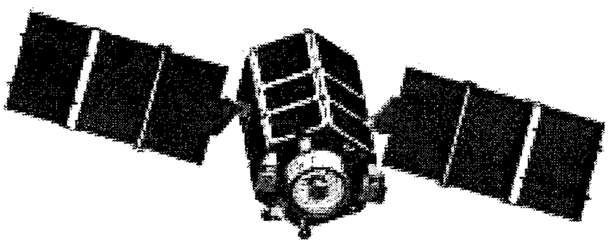

Figure 1. Typical Satellite (KOMPSAT – 2)

Since a satellite system is constructed with a combination of complicated HW and SW subsystems and satellite's dynamic motion in 3-dimensional inertial space environment, particular concerns is required to model for simulation. Proper modeling and simulation fidelity should be defined to satisfy simulation objectives effectively.

3 HIGH FIDELITY SATELLITE MODELING AND SIMULATION

3.1 Fidelity Definition

For the satellite modeling, high fidelity may be interpreted as "the closest realization of a satellite's functions and its motion in space". The fidelity of modeling and simulation directly depends on the objectives of the simulation.

High fidelity satellite simulation provides followings:

- Accurate satellite HW subsystem simulation
- Accurate satellite attitude and orbit dynamics simulation
- Flight software simulation
- High simulation speed
- Satellite operation simulation
- Versatile display tools
- Analysis tools for ground control system support

One of the issues of the modeling and simulation of a complicate system is the trade off between performance(mostly simulation speed) and simulation fidelity. For the case of satellite simulation, this issue should be resolved by the main objectives of the simulation.

3.2 Modeling a Satellite for the Simulation by Object-Oriented Methodology

High fidelity modeling and simulation requires co-work environment of multi number of experts. For a satellite modeling and development of a simulator, HW subsystem experts, SW engineers, and dynamics experts need to work together in limited time period. therefore an effective communication method for the experts and unified modeling and design tools are required for successful development. The object-oriented methodology[8,9] may provide a solution to this difficulty in development of a high fidelity satellite simulator.

OOA/OOD methodology generally provide a good co-work environment with effective communication method. In addition to this, object-oriented methodology may provide reusability, expandability, and reliability[8,9].

The object-oriented methodology provides very general and unified process for analysis and design of the target system.[9]. Next section we provide example of the OOA/OOD process that applied to KOMPSAT-2 high fidelity simulator development.

4 KOMPSAT-2 SIMULATOR

4.1 Structure and Services

KOMPSAT-2 Simulator (SIM) is one of the subsystems that compose Mission Control Element(MCE)[3]. MCE has four subsystems, Satellite operations subsystem(SOS)[3], Mission analysis and planning subsystem(MAPS)[10], Telemetry tracking and command subsystem(TTC), and SIM. In Figure 2, functional configuration and interface to other MCE subsystem are described. The hardware platform of SIM is Intel processor based PC server. Table 1 shows SIM hardware specification.

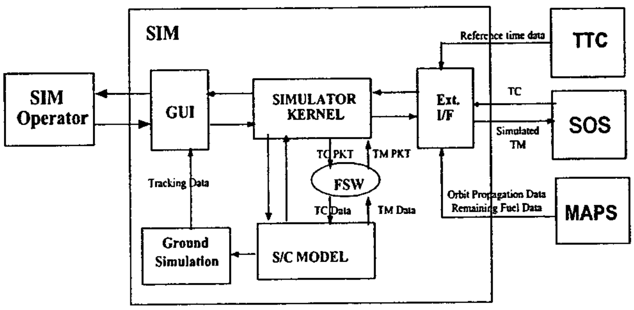

Figure 2 Software Functional Configuration

Table 1 Hardware Specification of SIM

Element	Specification
Simulator Main computer	- Main Memory (above 1GB) - Hard disk (above 20G *2) - Above 1.0GHz Intel CPU
Display device	- Color graphic monitor (21")
Interface	- Ethernet LAN transceiver

Main services of SIM are:

- TM/TC Process simulation
- Flight software simulation
- Attitude, orbit, and space environments simulation
- Simulation data display
- Data processing tools
- Static simulation support
- VR display
- Simulation playback
- Payload static simulation
- Real time connection service to satellite operation subsystem

With the above services, SIM may be used for operator training, anomaly simulation, static simulation for TC validation, attitude and orbit motion analyses, and etc.

4.2 Design

Unified Modeling Language(UML) is used for analysis and design process. UML provides effective tool for designing software system in unified format for developers .[9,11]

Design process are summarized as followings:

1. Use-Case Modeling
2. Domain Analysis
3. Architecture Design
4. Component Design
5. Class Detail Design

In Figure 3 , the Use-Case diagram is provided. Use –Case diagram is a result of Use-Case modeling which is a realization of functions of the system in the view point of users.

Domain Analysis performs how the Use-Case is realized in model. Domain Analysis is expressed by Class Diagram, which describes how these classes interact with each other.

Figure 4 shows that class diagram of "Satellite Simulation Use-Case" as an example of Domain Analysis. In Domain Analysis, objects extraction based on Use-Case Realization process by interaction diagram in Figure 5.

Architecture Design describes the system software architecture by defining components, packages, and processes, and their interfaces and dependencies. Figure 6 shows the Process View of the SIM as an example of the Architecture Design.

In Figure 7, main and related components in SIM is expressed. Each component, its interfaces and relations to other components are described in Component Design process.

Class Detail Design defines and describes all the operations and attributes (variables, parameters, etc) of the class. Figure 8 shows a class design of actuator classes and related classes as an example of Class Design of SIM.

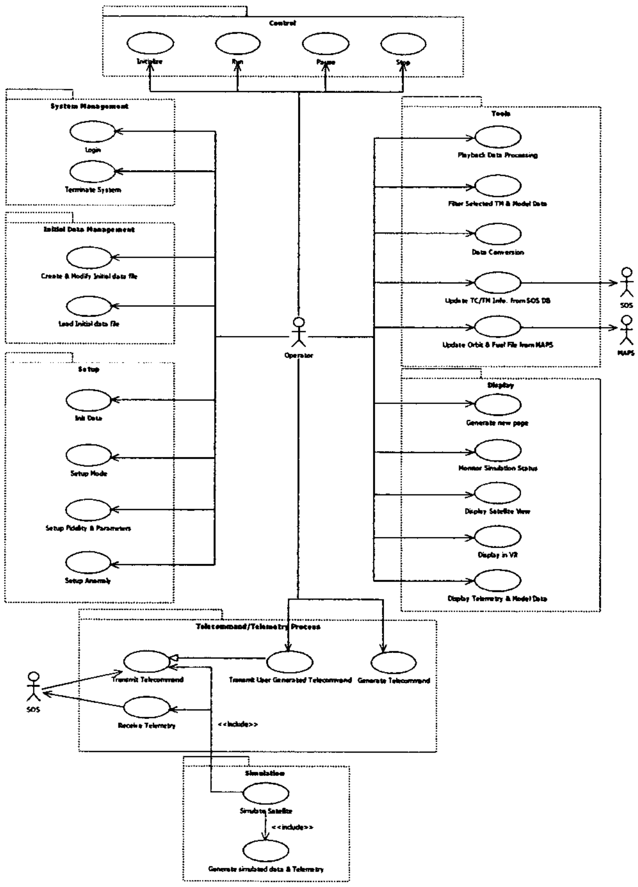

Figure 3 Use Case Diagram of SIM

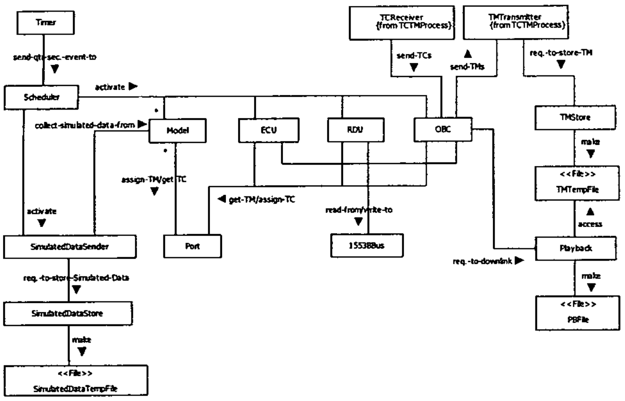

Figure 4 Class Diagram of Satellite Simulation

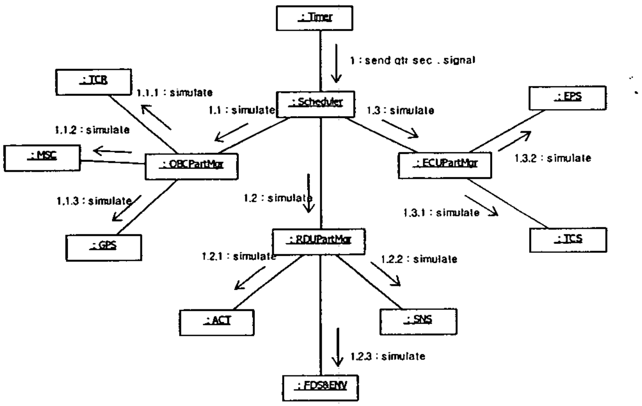

Figure 5 Interaction Diagram of Satellite Simulation

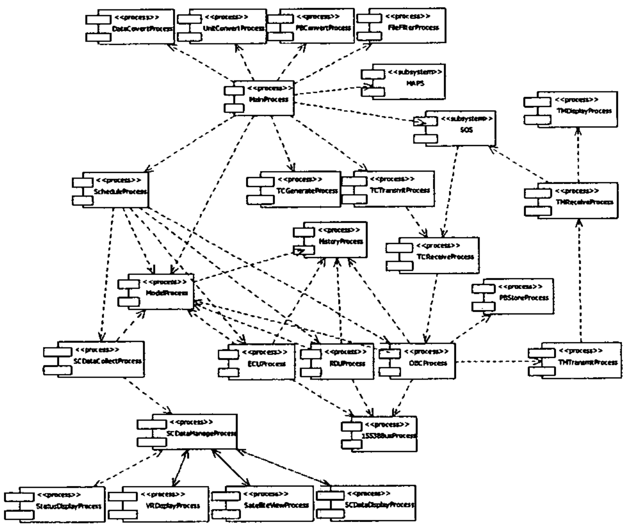

Figure 6 Process view of SIM

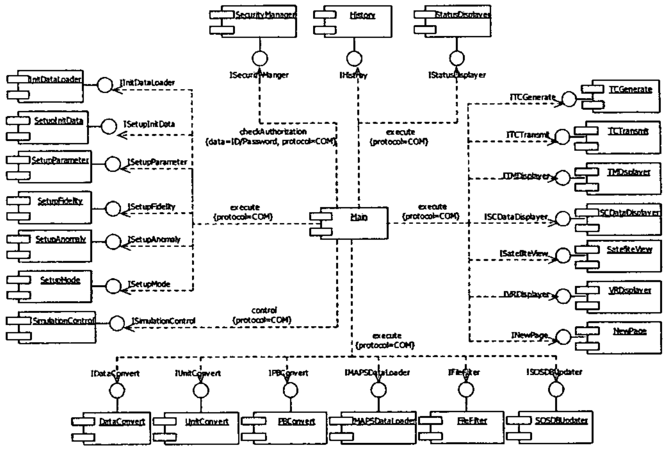

Figure 7 Overall Component of SIM

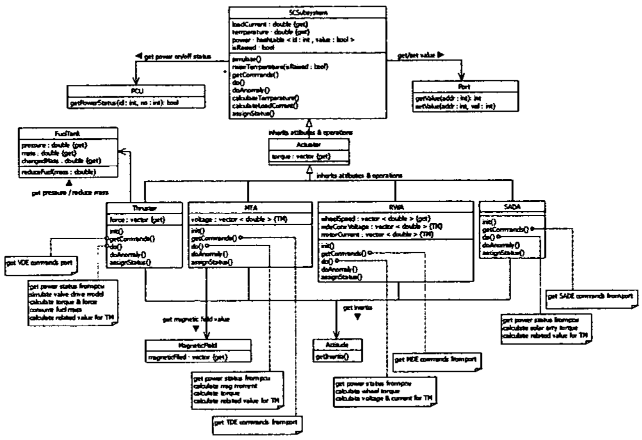

Figure 8 Class Design of Actuators and Related Classes

5 CONCLUSION

Satellite modeling and development of simulator by using object-oriented methodology is presented. Also high fidelity definition for a spacecraft modeling and simulation is discussed. Currently KOMPSAT-2 simulator development is in Class Detail Design phase. The object-oriented process has advantage of providing effective development environment for the high fidelity software satellite simulator development.

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AUTHOR BIOGRAPHIES

SUNGKI CHO is a Senior Research Staff of Communications Satellite Development Center at Electronics Telecommunications Research Institute, Taejon, Korea. He received his BS in Astronomy from Yonsei University, Seoul, South Korea in 1990, and MS and Ph.D in Aerospace Engineering from Auburn University, Alabama, US in 1995 and 1999, respectively. His research interests are in Dynamics and Control of Satellite. His email address is <soocho@etri.re.kr>.

SANGUK LEE is a senior research engineer of Communications Satellite Development Center at Electronics Telecommunications Research Institute, Taejon, Korea. He received his BS from Yonsei University, Seoul, Korea, in 1988 and MS and Ph. D. in Aerospace Engineering from Auburn University, Alabama, U. S. A, in 1991 and 1994, respectively. His research interests are in satellite dynamics and control, modeling, simulation, ground control system, and optimal control. His email address is <slee@etri.re.kr>.

JAEHOON KIM is a Project Manager in the Communications Satellite Development Center at ETRI. He received the Ph. D. degrees in computer engineering from Chungbuk National University, Cheongju, Korea. His research interests are satellite simulation, security in the satellite communications, fault diagnosis of satellite using AI technologies, and system modeling using objected-oriented technologies. His email address is <jhkim@etri.re.kr>

SEONG-PAL LEE is a Director of Communications Satellite Development Center at Electronics Telecommunications Research Institute, Taejon, Korea. He received his B.S. from Seoul National University, M.S and Ph.D. from Polytechnic Institute of New York. His interests include Satellite Communications System, Mobile Satellite Communication Service, Satellite Tracking & Telemetry & Command(TTC) System and Stratospheric System. His email and web addresses are <spallee@etri.re.kr>