Research on Integrated Operation Design of Low Orbit Remote Sensing Satellite for Intelligent Application

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Abstract. In this paper, from a remote sensing satellites that orbit earth operation characteristics and application conditions, combined with the elliptic orbit agile imaging and application characteristics of huge amounts of data transmission, and both remote sensing satellites that orbit earth in the next 10 to 20 years on the integration of electronic systems and application requirements of the system software, in view of the existing electronic system, the application of gap is given star to integration of heaven and earth satellite data application interface design, This paper provides a direction for the system software design of the future integrated electronic system on board.

Keyword: Low orbit · remote sensing satellite · in-orbit application requirements analysis · integrated operation design

1 Preface

Different from geosynchronous orbit satellites, low-orbit remote sensing satellites frequently enter and exit the country and work intermittently. The resources of reconnaissance, operation and controlcc and measurement and control arc are very valuable. Payload missions are intermittent (orbital characteristics), diverse (target characteristics) and uncertain (burst characteristics). Complex mission plans are made based on daily optimization and calculation of satellite and ground operation parameters.The satellite has a complex operating mode and strong orbital maneuver and attitude maneuver ability, which requires very high mission coordination and real-time performance of imaging payload, data transmission link, measurement and control link and platform.Due to the constraints of orbit, T&C and data transmission arcs are important resources for satellite in-orbit operation.At the same time, the on-orbit work of satellites is also restricted by orbit revisit characteristics, atmosphere, on-board system mission coordination (including attitude maneuver, storage, energy, payload working time), high data rate transmission, etc.

For remote sensing satellites that orbit earth transported accused of complicated, risky, high operation cost, etc., the research and development to use and easy to use

R. Li et al. (Eds.): MOBILWARE 2022, LNICST 507, pp. 269–284, 2023.
https://doi.org/10.1007/978-3-031-34497-8_23

software, the satellite has a strong ability of independent task management, including independent task management ability, independent health management ability, the ability of onboarrefactoring and automated testing capabilities, is the development trend of remote sensing satellites that orbit earth software design.

2 Demand Analysis of Low-orbit Remote Sensing Satellite In-Orbit Applications

2.1 Demand Analysis of Satellite Imaging, Data Transmission and On-Orbit Applications

Satellite Imaging Mode Analysis

At present, low-orbit remote sensing satellites can have strong agile maneuvering ability and realize the following agile imaging modes:

- Multi-target imaging in the same orbit: the satellite can frequently maneuver sideways to ensure the rapid completion of multi-point target imaging tasks.
- Multi-band splicing imaging mode in the same orbit: the attitude maneuver of the satellite in the direction of pitch and roll is used, and the piece-together push sweep along the track direction is carried out several times to obtain a wide multi-band splicing image.
- Multi-angle observation mode in the same orbit: push and sweep images of different facades of the same target were carried out through the pitch and roll of monorail and disorail satellites to obtain different facades information of the target that could not be observed in the traditional side-swing observation mode.
- The same orbit stereo imaging mode: using the high attitude maneuver ability of agile satellite, the satellite can observe the same area with different pitch angles in one orbit to obtain the information of different stereo planes of the same ground object, and finally complete the stereo mapping function through the ground processing.
- Continuous strip imaging mode: the satellite images subsatellite points or ground targets continuously at a certain pitch Angle with high attitude stability and high attitude pointing accuracy.To improve the timeliness of imaging, the satellite imaged long and narrow ground objects in the non-track direction (Fig. 1).

The typical agile imaging mode is shown in the figure below.

Analysis of Satellite Massive Data Transmission Mode

As shown in Fig. 2, compared with the low-orbit remote sensing satellite developed in 2013, the payload data volume of the satellite developed in 2018 has increased by 20 times, while the storage capacity has only increased by 4 times, the earth-to-earth data transmission capacity has increased by 2.3 times, and the relay data transmission capacity has increased by 2.0 times Fig. 2**.**

As shown in Fig. 3, compared with the low-orbit remote sensing satellite developed in 2013, the imaging power of the satellite developed in 2018 increased by 5.6 times, the earth playback power increased by 13.3 times, and the relay playback power increased

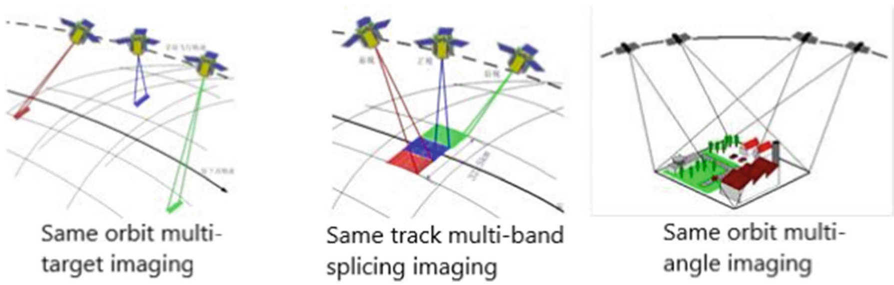

Fig. 1. Typical agile imaging mode of satellite

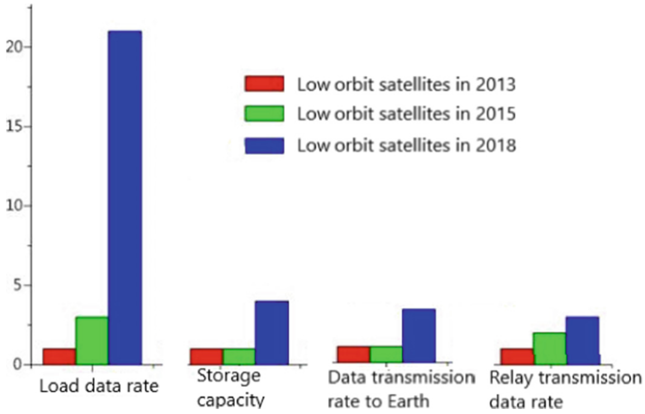

Fig. 2. Evolution diagram of satellite data balance configuration-

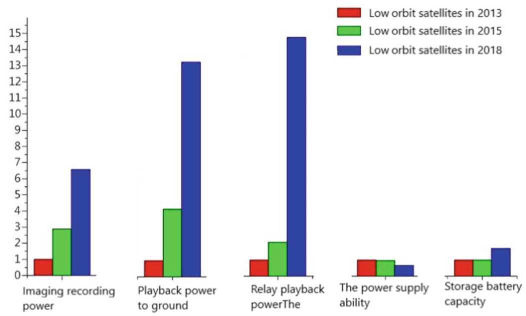

Fig. 3. Evolution diagram of satellite energy configuration-

by 14.8 times. Figure 3 the satellite power supply capacity is reduced by 22.4%, and the battery capacity is increased by 71.4%.

The new generation of low-orbit remote sensing satellites can improve the load data transmission capacity by improving the modulation mode, coding mode, increasing

EIRP, polarization multiplexing and other means. At the same time, the satellite integrated electronic system adopts the dynamic cooperation system of energy, storage and data transmission resources to improve the data storage and transmission efficiency, so as to support the acquisition and transmission of massive data.

The new generation of low-orbit remote sensing satellites has the following capabilities:

- The scheduling strategy of "pre-pointing and cross-using in advance" is adopted to reduce the loss of data transmission arcs caused by antenna cutting stations;
- Intelligent cloud judgment algorithm is used to eliminate the useless massive information and improve the efficiency of effective information transmission.
- The preprocessing technology is used to provide end-to-end in-orbit data service for tactical users.

Analysis of In-Orbit Autonomous Focusing Requirements of Satellites
The imaging of low-orbit remote sensing satellites with different attitudes in orbit will lead to the large difference of object distance between imaging tasks, which will bring a certain degree of defocus. The focus strategy planning is carried out according to the influence of the decrease of the defocus transmission function of the camera in orbit is not more than 5%, that is, the focal plane of the camera must be adjusted when the cumulative defocus amount reaches $\pm\delta/3$ (±0.07 mm).

(1) Analysis of the focusing requirement of passive push and sweep mode

- Elliptical orbit

  The change rate of object distance caused by the change of orbit height does not exceed 0.35 km/s in the range of common attitude maneuver of passive thrust-sweep. Meanwhile, under the current orbit design and camera optical system design, the minimum change of object distance corresponding to 1/3 focal depth change of image distance is 15 km(246 km ~ 260 km).

  A. Calculate the change rate of object distance caused by the change of orbit height and the corresponding time of defocus threshold under the condition that the satellite attitude remains unchanged in the process of passive push and sweep orbit lifting and orbit lowering. It can be seen that within the range of commonly used attitude maneuver, the shortest time for the defocus caused by orbit height to reach the defocus threshold is about 100s. That is, theoretically, when a single image is passively pushed and swept for 100s, the focus plane position can be reasonably set to ensure that the defocus in a single image does not exceed the defocus threshold. If a larger attitude maneuver Angle, such as 45°, is considered, then when the single imaging time is less than 40s, no focusing is required during the imaging period.
  B. At the same time, if only the defocus caused by the attitude maneuver is considered, the minimum point-to-point attitude maneuver Angle corresponding to the defocus threshold is about 20° and the corresponding attitude maneuver time is about 48s(stability $5 \times 10)^{-4}$°/s)/28s (stability 2×10^{-3}° / s). At the same time, during 48s/28s, the orbital height of the satellite may also change about 10km/5km, that is, in the worst case, the attitude maneuver between the

two targets of the satellite may not exceed 20°, but it may also need to focus. At this time, excluding the stabilization time after focal plane adjustment, the shortest time window for focusing between the two missions is about 40s/20s. When the two tasks are very close to each other, the controller should be powered on during the two tasks in order to complete the focal plane adjustment.

C. The actual situation of in-orbit mission arrangement is more complicated than the single factor analyzed in this paper. Factors such as orbit height change, attitude maneuver Angle and direction between two imaging, and orbit rise/fall will exert a combined effect on the change of focal plane position during two imaging. Therefore, for each imaging task, the acceptable focal plane position interval should be calculated separately, and the focus decision should be made. When the user arranges the imaging mode, it can be analyzed according to the specific situation.

- Circular orbit

  The satellite adopts passive thrusting mode in orbit, so the change of object distance during a single mission imaging is mainly caused by the change of elevation, and the maximum surface elevation is not more than 9 km, which is far less than the change of object distance corresponding to the acceptable defocus threshold when the object distance is greater than 490 km. Therefore, it can ensure that no focus is needed during a single imaging.

  The change of object distance between missions is mainly caused by the attitude Angle and the elevation of the satellite. Since the change of object distance caused by elevation change is small, the change of object distance caused by attitude maneuver Angle change is shown in the following table (Table 1).

Table 1. Object distances corresponding to different attitude angles of circular orbit

Attitude Maneuver Angle (°)	5	10	15	20	25	30
Object distance (km)	492.0	498.1	508.7	524.1	545.3	573.3
Attitude Maneuver Angle (°)	35	40	45	50	55	60
Object distance (km)	609.9	658.0	721.9	809.3	934.8	1131.6

From the above table:

- When 0° $\leq$ attitude maneuver Angle (relative subsatellite point) $\leq$ 25°, the same focal plane position can be adopted.
- When 25° < attitude maneuver Angle (relative subsatellite point) $\leq$ 35°, the same focal plane position can be used.
- When 35° < attitude maneuver Angle (relative subsatellite point) $\leq$ 45°, the same focal plane position can be used.
- When 45° < attitude maneuver Angle (relative subsatellite point) $\leq$ 50°, the same focal plane position can be used.

- When 50° < attitude maneuver Angle (relative subsatellite point) ≤ 60°, the same focal plane position can be used.

Therefore, in circular orbit imaging, different attitude maneuver angles of the satellite -- the annular map of focal plane position can be calculated. When the attitude maneuver angles of two adjacent imaging missions are different, focal plane adjustment will be needed.

(2) Analysis of the focus requirement of active push and sweep operation mode.

Active sweep mode is mainly used in elliptical orbit near Earth arc.In active sweep mode, the imaging time of a typical imaging task is 20s. According to the design conditions of 96(the most commonly used on-orbit) and 48 (the least commonly used on-orbit) integration series, the integration time corresponding to 54 μs (level 48) and 27μs(level 96), the simulation analysis is carried out. In the process of analysis, a total of 8 characteristic orbital heights were selected for the near-earth arc with the orbital height of 250 ~ 490 km, and one characteristic value was selected for every 10 degrees of the side-swing Angle of the imaging center from 0 to 40 degrees.

Within the orbit range of 250–490 km, the change of object distance is no more than 10 km within 20 s of a single active scan, and the minimum change of object distance corresponding to the defocus threshold is 15 km. That is, after the focal plane position of the imaging task is properly set, the focal plane position does not need to be adjusted during the single active scan.

For the focus requirements between adjacent tasks, active backscanning is more complicated than passive thrusting. Besides the time needed to switch orbit height and attitude Angle, the establishment time of attitude angular velocity should also be taken into account.Via simulation, establish active flyback attitude about 60 s longest, imaging position return to zero after the completion of time of about 80 s, both the sum of the time, caused by orbital altitude change as is close to or more than from the focal distance change threshold, consider adjacent tasks at the same time image center points to differences, a single imaging distance real-time variation during the influence of such factors, It is more difficult to set a general judgment condition to determine whether to focus or not. Therefore, it is necessary to calculate the decision focusing action before each imaging mission according to the orbit, task information, current focal plane position, etc.

2.2 Analysis of Efficient Satellite Measurement and Control, Operation and Control and Application Requirements

The requirements of satellite in T&C and O&C are as follows:

- Efficient mission injection: with the rapid growth of the attitude and maneuver ability of satellites, the number of missions carried by satellites grows rapidly every day, so it is urgent to improve the efficiency of mission injection.
- Autonomous closed-loop operation and control optimization: Satellite business data mass growth, a variety of imaging model, a variety of tasks orbit of different control strategies, to receive, decomposition, scheduling tasks require satellite system,

detection and control to realize comprehensive optimization, consider including orbit, imaging model, agile attitude maneuver, data transmission, energy, store a variety of factors such as stars, fine management, in order to realize the star - integration optimization using, To improve the application efficiency of the system;

- User-oriented control: application satellites in orbit and attitude maneuver ability, energy, ability, tactical service aspects put forward the new requirements, independent task management was adopted to realize the demand of various application environments, a support long-focus camera elliptical orbit environment, support for multiple attitude maneuver strategy, to support the whole closed-loop energy management, etc.;
- Emergency mission response: the satellite has the ability to respond to emergency missions directly without the ground operation and control system.
- Software maintenance: Most of the on-board software has maintenance capability, which can adapt to AIT test and adapt to various orbital imaging applications in orbit.

2.3 Analysis of Requirements for Autonomous Mission Management

Low-orbit remote sensing satellites have the capabilities of attitude maneuvering, imaging control, data transmission and resource optimization, which puts forward higher autonomous management capabilities for on-board integrated electronic systems, and requires them to meet the requirements of multi-mission, high-dynamic, multi-application orbit and high-precision autonomous mission management with higher collaboration and real-time performance. The on-board integrated electronic system needs the capabilities of incremental mission planning, mission optimization, decomposition, scheduling, and collaborative data service.

- Incremental mission planning: JB-16 satellite has the capability of incremental mission planning, realizing autonomous timing conflict detection, autonomous data balance management, mission arbitration, on-board resource balance, etc., and rapidly responding to emergency imaging services.
- Decomposition: the user's various application modes are decomposed into basic working modes, and the number of basic working modes is reduced by combining the modes to reduce the complexity of implementation, testing and autonomous health management.
- Scheduling: reasonably arrange the timing of task-related parameter calculation, instruction generation, focus, refrigerator switching and platform data processing to ensure the rationality of task-related equipment control scheduling;
- Task optimization: improve system efficiency through task parallelization; Based on the "critical path" optimization method, the camera power consumption during continuous imaging is reduced. Satellite-ground integration analysis software is used to autonomously arrange the satellite attitude swing according to the time interval of continuous imaging missions. Based on the task distribution, the focus, memory clearing, data preprocessing and other tasks were arranged by selecting the machine. Affected by the uncertainty of elliptical orbit operation, real-time satellite calculation is used to realize in-motion imaging according to the imaging latitude and longitude information injected from the ground, and the imaging time error and orbit prediction

error caused by the long prediction time of the traditional ground operation and control mode are corrected.

- Collaborative data service: Imaging satellites need load, control, dual mode, data processing, antenna receiver, task management computer, load data processing, such as computers, work together to achieve user tasks in a timely and high quality, especially the control subsystem, camera subsystem, data transmission subsystem, navigation receiver to work together to achieve perigee flyback, The navigation receiver, control subsystem, and integrated electronic subsystem cooperate to provide fast and low-delay integration time data service, and adjust the camera integration time in real time during the backsweep attitude maneuver imaging process.

2.4 On-Board Autonomous Health Management and On-Orbit Maintenance Requirements Analysis

- Autonomous health management: satellite operating mode is complex, data flow relationship is complex, complex application mode, it is urgent to use on-board autonomous health management to improve on-orbit support capacity;
- Mission operation process monitoring: the satellite uses on-board mission management to achieve autonomous operation and control. The ground system lacks prior knowledge to predict the working status of the satellite, and the satellite automatically diagnoses the health status according to the real-time operating status.
- Health evaluation: it provides health evaluation capability to facilitate users to take necessary maintenance measures.

2.5 Automated Test Requirement Analysis

Intelligent testing methods are urgently needed to reduce testing cost and shorten development cycle for satellites.

- Incremental verification: the product status of each subsystem is new, the development difficulty is inconsistent, and the function is highly coupled, so it must have the incremental verification feature to ensure the credibility of the test verification when the equipment is not fully set.
- Automatic mode test and orthogonal test: satellite platform, load working mode highly coupled, more attitude maneuver model, three kinds of application environment, system working mode/validation test sequence mass growth, test verification cycle is long, need to be improve work efficiency and automation model test and orthogonal test, on the premise of ensure testing strength, ensure the reliability of the satellite design;
- Temporal fault immune design: satellite requires highly coordinated platform and payload, and high frequency and low delay data services make system verification more difficult, so it is urgent to adopt time-driven design system.
- Software without assembly maintenance: the high-coupling design makes the whole satellite test the only link of system physical verification. When the ground test encounters a fault, the SMU, CCU and other complex software with multiple interfaces and large scale can be updated online without assembly.

- Interlock protection of dangerous instructions: multiple protection measures jointly designed by software and hardware are adopted to ensure that the satellite equipment will not be damaged by errors in the operation of test sequences of explosive products, propulsion and moving parts.

3 Gap Analysis

3.1 Task Management

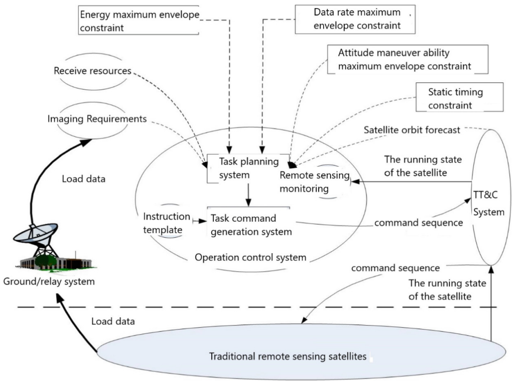

Fig. 4. Traditional satellite mission management mode-1

As shown in the figure above, the traditional satellite mission management mode has the following shortcomings:

- Poor coordination and real-time performance between platform and payload mission: At present, all satellites are static mission management, which cannot meet the requirements of high-dynamic and multi-mission missions. That is, both platform and payload work in serial mode, and the imaging control chain is slow and not real-time, which does not meet the real-time control requirements of dynamic parameters of satellite attitude maneuver imaging (Fig. 4).
- Poor resource management ability and low combat effectiveness: as the "passive executor" of the mission command sequence of the ground operation and control system, the satellite lacks the ability to optimize user tasks according to the real-time operation state, and the utilization of on-board resources, satellite-ground transmission resources and ground resources is low.
- Poor response ability to emergency missions: satellite applications rely on the ground mission planning system, so they cannot directly receive emergency missions, realize mission planning independently, and directly serve tactical users.

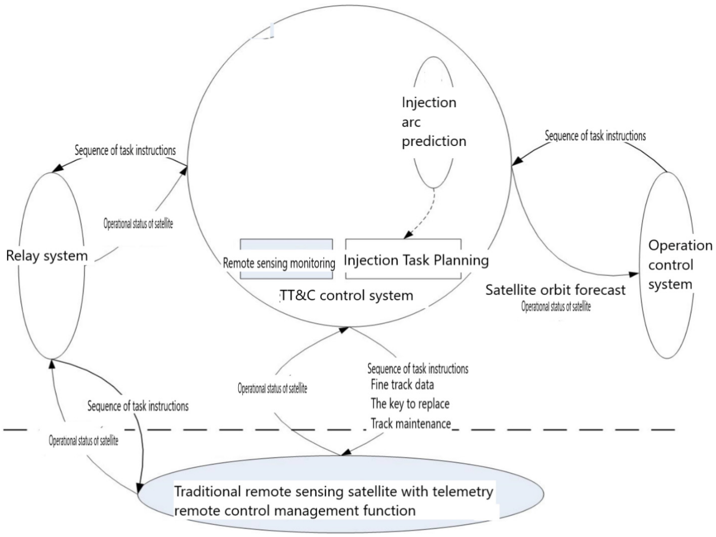

Fig. 5. Traditional satellite TT&C control management mode2

3.2 TT&C and Operation Control

As shown in the figure above, the traditional satellite TT&C management mode has the following shortcomings:

- The mission injection efficiency is low: the ground system directly controls the on-board equipment and sets imaging parameters based on the command template, the command template increases exponentially, the utilization of measurement and control resources is low, and the satellite operation and control cost increases significantly, which cannot meet the rapid growth requirements of reconnaissance and illumination missions caused by the rapid improvement of attitude maneuver capability.
- Lack of user-oriented maneuvering design: lack of user-oriented system-level design, high control threshold, users need to know technical details before using the satellite, complex satellite-earth system operation and control, poor equipment capability; User manipulation errors may affect the success or failure of the mission, or even bring catastrophic effects to the operation safety of the satellite.
- Mission planning with large time delay between earth and earth cannot be optimized in real-time operation and control. There are many satellite imaging modes and different orbit operation and control strategies, and the predicted orbit, agile attitude maneuver, data transmission, energy and on-board storage strategies based on the ground system are rough in resource management, and the overall efficiency is low (Fig. 5).

3.3 Health Management

- On-orbit service is not guaranteed: at present, satellites lack independent health management ability. Ground personnel diagnose satellite status based on original telemetry. The satellite operation mode is complex, and original telemetry interpretation requires professional knowledge and is difficult to interpret.With the rapid increase of the number of satellites in orbit, manual interpretation will be more difficult, and the on-orbit operation of complex satellites lacks reliable guarantee conditions.

- The ground maintenance cost is high: the capacity of T&C channel is limited, the original information is too much, and the ground maintenance cost is high.
- Poor fault location ability: when the satellite is faulty, overseas telemetry can only locate the time period when the fault occurs, and the on-orbit maintenance time is long, which affects the use of users.
- Lack of health evaluation ability: the necessary maintenance measures cannot be taken in advance, and the fault is not handled in time;
- Lack of on-orbit maintenance ability: most on-board software cannot be maintained, and poor adaptability to changes in application conditions/usage constraints;
- Low level of autonomous management: over-reliance on artificial decision-making on the ground, inadequate and timely on-board safety protection measures for emergency failures, and high risk; Except for the control system, all the other systems have no autonomous management ability, which still stays at the low level of the ground switchover, and lacks the system-level safety management strategy and reconstruction strategy, and the satellite operation robustness is poor.

3.4 Test Automation

- The lack of system-level design for fast testing, fault diagnosis and security protection leads to long development cycle and high development cost. The system-level test mode increases exponentially with the user usage mode. The whole process from the whole satellite development to the orbit application relies too much on the ground manual test, interpretation and diagnosis;
- Test no incremental: at present, the remote sensing satellite based on strength test verification system functions, test results closely related to product running environment, single machine testing, subsystem and try and bus, the star test, environment test, test results do not general, lead to more testers, test, strength, testing cycle is long, high test cost;
- Exponential growth of test mode: Currently, remote sensing satellites carry out enumeration test of working mode based on instruction template, and the test verification sequence of complex satellites increases exponentially, resulting in high test and verification cost.
- There are many timing conflicts: At present, remote sensing satellites use event-triggered mechanism to realize work cooperation. More than 90% of the quality problems in satellite system integration are related to timing conflicts, and the timing error location analysis is difficult, the probability of recurrence is low, and the detection cycle is long, which seriously affects the test schedule.
- High software maintenance cost: lack of self-test-oriented design, ground test in the event of failure, disassemble equipment to zero or replace equipment, long troubleshooting cycle.

4 Integrated Operation Design of Heaven and Earth for Intelligent Applications

The new generation of integrated satellite electronic system is advanced in design and can meet the requirements of tactical applications in the field of medium-low orbit remote sensing satellites in the next 10 to 20 years. The satellite is maneuverable, has independent operation, management and survival capabilities, and has the ability to continuously optimize combat performance throughout its life cycle, providing users with high-resolution, multi-imaging mode and high-availability tactical services. Guided by satellite technology innovation, the satellite-ground integration optimal design meets users' application requirements for high performance satellites to be easy to use and easy to use.

The new generation of integrated satellite electronic system has a high level of intelligence, new technical status and complex functions. The operation and control mode, measurement and control mode, relay application mode and on-orbit maintenance mode of traditional satellites have all undergone significant changes. This chapter defines the technology status of satellite-earth data interface, which is used as the input for the design of satellite subsystems.

As shown in the figure below, the new satellite-earth data interface is explained.

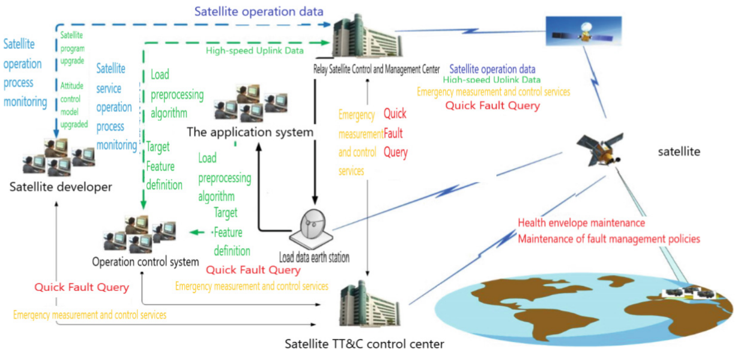

Fig. 6. Architecture of satellite satellite-Earth interface-1

4.1 Transport Control Interface

The satellite operation and control system realizes the transformation from static mission planning to dynamic mission planning, from dedicated operation mode to general operation mode, and from satellite-earth open-loop management to satellite-earth closed-loop management. The new generation of satellite-earth data interface is shown in Fig. 6, and its features include: Fig. 7.

1) Construct a digital satellite model, dynamically modify the usage constraints based on the on-board real state, and change from static mission planning to dynamic mission planning to improve the utilization efficiency of bottleneck resources:

- Energy balance management: change the static constraint of energy "circle balance", realize dynamic energy calculation based on satellite Pro/E model, and arrange user tasks based on "battery discharge safety depth" to improve the efficiency of satellite energy use.
- Storage resource management: the static storage estimation mode and data playback mode of "record interface rate × recording time" were changed to dynamically estimate the amount of imaging data based on attitude, orbit and digital map to improve the on-board memory usage efficiency.
- Transmission arc management: the data arc is estimated according to the real configuration, attitude, and orbit of the satellite, and the playback data is dynamically arranged based on the "actual data volume and task priority" to improve the efficiency of the data arc.

2) Business-oriented control interface is adopted to improve task injection efficiency, avoid irregular operation security risks, and realize the transformation from dedicated control mode to general control mode:

- Satellite control specifications: establish unified, efficient and easy to use satellite and ground control specifications.
- Dynamic timing analysis: Develop a "satellite autonomous command generation and optimization simulation system" to dynamically simulate agile imaging, data playback, recording and playing, camera focusing, antenna presetting, retention cleaning, data preprocessing, platform data processing and other processes, so as to avoid timing conflicts during task scheduling.

3) A closed-loop operation control optimization mechanism of forecasting-execution-Checking-correction (PDCA) was constructed to achieve an efficient and practical business process through integrated satellite-ground design:

- Innovation of satellite-land collaboration mode: Change the traditional satellite on-orbit application according to the state at the end of life, and users can't the lack of "dynamic" adjustment key operation parameters, a day to receive satellite operation data, analysis the actual operation process and the ground "digital satellite model" to predict differences, regular fixed energy model, the attitude maneuver model and so on, implementation strategies and satellite features matching, To realize the fine operation and management of the whole life cycle of the satellite.
- Rapid maintenance design: To change the shortcomings of tight coupling of traditional satellite satellite-based design, rapid reconfiguration of satellite application

strategy can be achieved without upgrading ground software, and multiple imaging modes and multiple orbits can be supported.

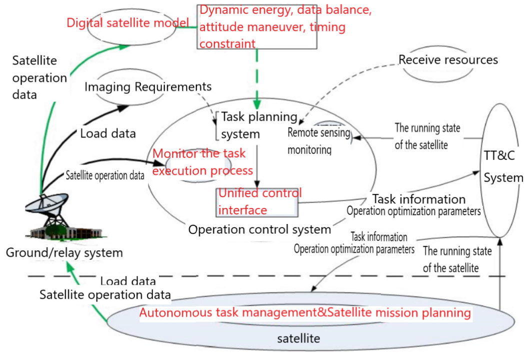

Fig. 7. Architecture of the new generation of satellite operation and control interface-

4.2 TT&C Control Interface

The satellite TT&C system has been transformed from business support and operation monitoring to high and stable operation, high availability of services and long life guarantee in orbit. The satellite-ground data interface is shown in Fig. 8. Its features include:

1) Build a digital satellite model, improve the use efficiency of measurement and control arcs based on the real state of the satellite, and improve the on-orbit monitoring capability of the satellite:

   - TT&c arc simulation: a satellite TT&C antenna occlusion model was constructed to provide accurate TT&C arc prediction for the TT&C system and improve the use efficiency of agile satellite TT&C arc based on user task distribution and TT&C antenna configuration layout characteristics.
   - Operation process simulation: the satellite operation process model is constructed to expand the user task into an on-orbit command sequence, provide the occurrence time of each action on the satellite and the corresponding satellite state, provide accurate operation state prediction for the TT&C system, and improve the ground monitoring and fault diagnosis ability.

2) Construct a closed-loop optimization mechanism of foreseeing-execution-checking-correction (PDCA) for autonomous health management, and achieve efficient and practical autonomous health management through the integrated design of satellite and earth:

   - Health management strategy modification: according to the real on-orbit operation state of the satellite, the autonomous health management model is added and modified to continuously improve the autonomous operation management level of satellite.

- Health envelope modification: according to the real on-orbit operation state of the satellite, the health envelope of key characteristic parameters is regularly modified to achieve the matching between the health diagnosis strategy and the characteristics of the satellite, and to achieve the refined autonomous health management of the satellite throughout its life cycle.

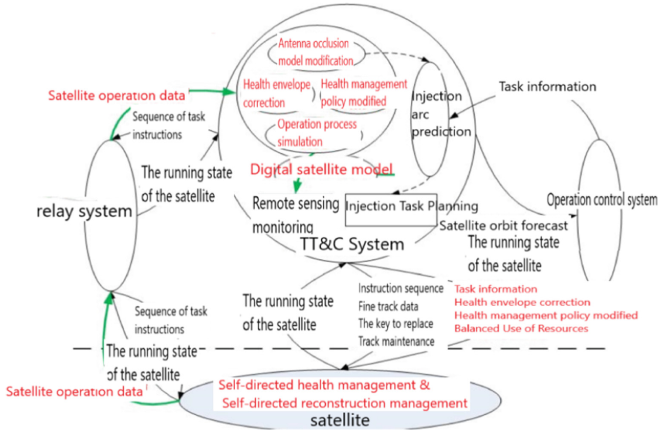

Fig. 8. The interface architecture of the new generation of satellite measurement, control and control-

4.3 Relay Interface

The satellite relay system provides high-speed uplink data injection, satellite operation process data downtransmission, and independent establishment of emergency measurement and control chain to meet the needs of satellite applications. Its features include:

- High-speed uplink injection management: configure the ground equipment required by high-speed uplink (5Mbps) to optimize the satellite operation and control strategy, upgrade the payload preprocessing algorithm, inject the mission-related data form and calculation model, optimize the space attack and defense strategy, and upgrade the onboard software, etc.
- Satellite operation process data transmission: provide detailed original data of satellite operation process for operation control and application systems, measurement and control systems, and satellite developers, and realize closed-loop optimization of satellite operation management.
- Autonomous chain construction for emergency TT&C: The relay system senses the emergency TT&C request of the user star by using the idle time window. When the user star has a serious fault that the autonomous management strategy fails, it

immediately autonomously allocates the T&C channel, notifying the ground system of the emergency TT&C request of the user star, and the ground system starts the emergency rescue procedure.

5 Conclusion

Based on the operational characteristics and application constraints of low orbit remote sensing satellite, combined with the application characteristics of agile imaging and massive data transmission of a satellite, and considering the application requirements of integrated electronic system and system software of low orbit remote sensing satellite in the next 10 ~ 20 years, aiming at the application gap of the existing electronic system, The design of the satellite-earth data application interface, operation and control interface, measurement and control interface and relay interface of the integrated satellite is given, which provides guidance for the system software design of the integrated on-board electronic system.

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