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Time allocation scheme for the WSO-UV mission

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The World Space Observatory — Ultraviolet (WSO-UV) is an international space observatory for observation in UV spectral range 100-350 nm, that is beyond the reach of ground-based instruments but where most of astrophysical processes can be efficiently studied with unprecedented capability. The WSO-UV project is funded by national space agencies of Russia and Spain with participation of Germany, Ukraine and China. The WSO-UV consists of a 1.7 m aperture telescope (under responsibility of Russia) with instrumentation designed to carry out high resolution spectroscopy, long-slit low resolution spectroscopy and direct sky imaging. The WSO-UV Ground Segment is under development by Spain and Russia. They will coordinate the Mission and Science Operations and provide the satellite tracking stations for the project.
The WSO-UV will work as a targeted scientific observatory. Three scientific programs will be carried out at the observatory.
Core Program of scientific observations, which deserves large amounts of observing time, will be defined by the WSO-UV Science Committee to allow the conduction of high impact or legacy scientific projects. Funding Bodies Program is the guaranteed time granted to each one of the national bodies funding the WSO-UV project. Guest observer program for everyone, or Open Program, consists of astronomical observations obtained with the WSO-UV by astronomers who may or may not belong to the WSO-UV international consortium. It is open to excellent scientific projects from the world-wide community and occupies up to 40% of total observational time.
A brief summary of the algorithmic strategies analyzed for scheduling optimization is also presented in the paper.

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1. World Space Observatory — Ultraviolet

The aim of the World Space Observatory — Ultraviolet (WSO-UV, [1, 2], wso-uv.org) mission is to study the Universe in the 100-320 nm range, that is beyond the reach of ground-based instruments but where most of astrophysical processes can be efficiently studied with unprecedented capability. The WSO-UV has been driven by the needs of scientists to have an UV facility in the horizon of the next decade. It will be the only large telescope class mission for UV observations in post Hubble Space Telescope (HST) era. By its potential, the WSO-UV mission is similar to the HST, though it exceeds the HST in spectroscopic capabilities.

WSO-UV is an international collaboration involving researchers from different countries with Russia playing the leading role. The project has been included into the Federal Space Program of Russia. The Institute of Astronomy of the Russian Academy of Sciences and Lavochkin Industries act as responsible organizations for the payload and space complex, respectively.

The main instrument of the observatory is a 170-cm telescope based on the classic Ritchey-Chretien scheme. Main parameters of the telescope are the following:

primary mirror diameter is 170 cm,

focal length is 1700 cm,

field of view is 30 arcmin,

image quality is diffraction limited at the center of the field of view.

The main units of the structural model of the T-170 prototype telescope have successfully passed vibrostatic and thermal vacuum tests. The primary mirror and other optical elements is being manufactured by the Lytkarino Optical Glass Factory (Russia). The T-170M telescope has assimilated the successful experience gained during the fulfillment of the "Astron" [3] project. The telescope is equipped with spectrographs for performing analysis of UV spectra and cameras for high-quality UV and optical imaging.

The spectrograph unit comprises three different single spectrographs: two high-resolution spectrographs, namely, UV Echelle Spectrograph, UVES (174-310 nm, 50000) and Vacuum UV Echelle Spectrograph, VUVES (102-172 nm, 55000) [4], as well as a Long-Slit Spectrograph, LSS (102-310 nm, 2500) [5]. Wavelength range and spectral resolution are indicated in the brackets. Such characteristics will make it possible to perform detailed spectral analysis of objects up to 15-17 mag. LSS is aimed at observations of fainter objects (e.g. distant galaxies) with the moderate dispersion.

The WSO-UV field camera unit, Imaging and Slitless Spectroscopy Instrument for Surveys (ISSIS), is being developed by Spain to carry out UV and optical diffraction limited imaging of astronomical objects. The ISSIS incorporates two channels: High Sensitivity Far-UV Channel (120-200 nm) and the Channel for Surveys (120-800 nm). In addition to direct imaging, ISSIS will provide slitless spectroscopic capabilities.

The Fine Guidance Sensors System (FGS, under development by Russian Space Research Institute) is intended for precise pointing (0.03 arc sec) and stabilization of the telescope during a scientific observation session. The FGS consists of 3 guiding sensors located near the entrance slits of spectrographs and the common Data Processor Unit. The working part of the Master Catalogue for the FGS is stored in the Data Processor Unit and contains coordinates of guiding stars up to

R=17 mag. Main characteristic of FGS are the following: pointing and stabilization accuracy is 0.03 arcsec, period of information updating is 0.5-2 sec, spectral range is 450-750 nm.

The telescope is planned to be launched in 2013 by a Zenit-2SB medium-class launcher equipped with a Fregat accelerating module. All launch facilities will be provided by Russia. The observatory is expected to operate for about 10 years. A geosynchronous orbit with an inclination of 51.8 degrees has been chosen. For this orbit the effects of the radiation belts will be negligible.

2. Ground segment

The Ground Segment, including the mission control segment and ground-based science segment, is a very important component of the WSO-UV project. The mission operation center (MOC, two fully mirror distributed parts located in Spain and Russia) with co-located control centers and ground stations are parts of the Ground Control Segment. The core of the Ground-based Science Segment is the Science Operation Center (SOC, two fully mirror distributed parts located in Spain and Russia), which can be linked to various research centers (institutes, universities, etc.). The users, i.e., the researchers who have their applications included in the observing program, and those interested in obtaining research data stored in archives will be able to access the SOC via communication links. Ground Segment scheme and Science Operation Center scheme (current version) are presented in Figs 1 and 2, respectively.

3. Scientific Programs

WSO-UV will work as a space targeted observatory with a core program, an open program for scientific projects from the world-wide community and national (funding bodies) programs for the project partners.

Core Program (CP) of scientific observations with the WSO-UV is defined to allow the conduction of high impact or legacy scientific projects that deserve large amounts of observing time. The projects are selected on the basis of their scientific excellence.

Open Program (OP) consists of astronomical observations obtained with the WSO-UV by astronomers who may or may not belong to the WSO-UV international consortium.

Funding Bodies Program (FBP) is the guaranteed time granted to each one of the national bodies funding the WSO-UV project.

Time Allocation Committee (TAC), appointed by the Agencies funding the project, will select the scientific programs for the CP and the OP. National Time Allocation Committees will select the scientific programs for the FBP.

4. Telescope time during nominal scientific operations

After the *Commissioning Phase* and *Calibration and Performance Science Verification Phase*, the regular observations will start. The telescope time available for astronomical observations will be divided in

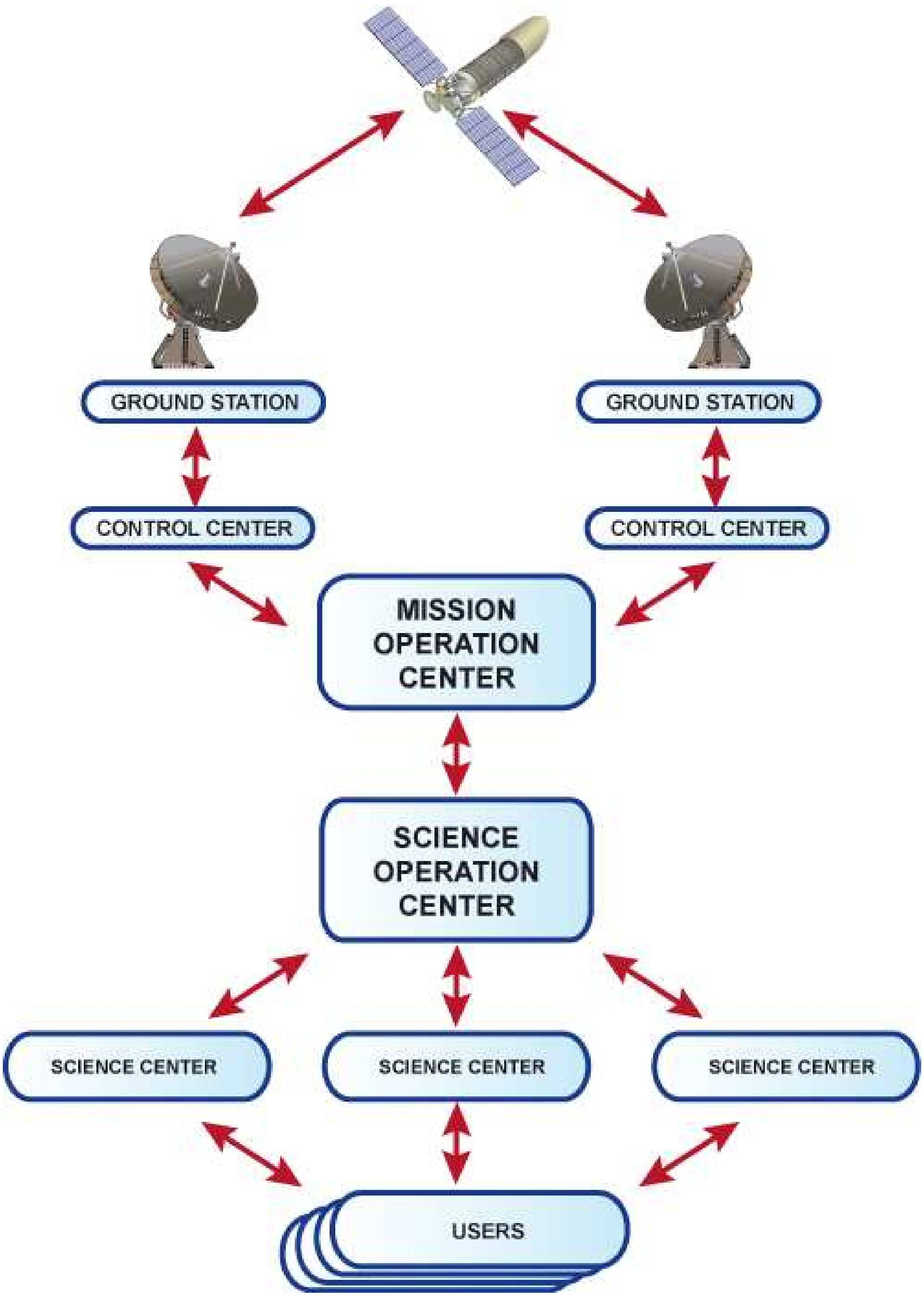

Figure 1: Ground Segment

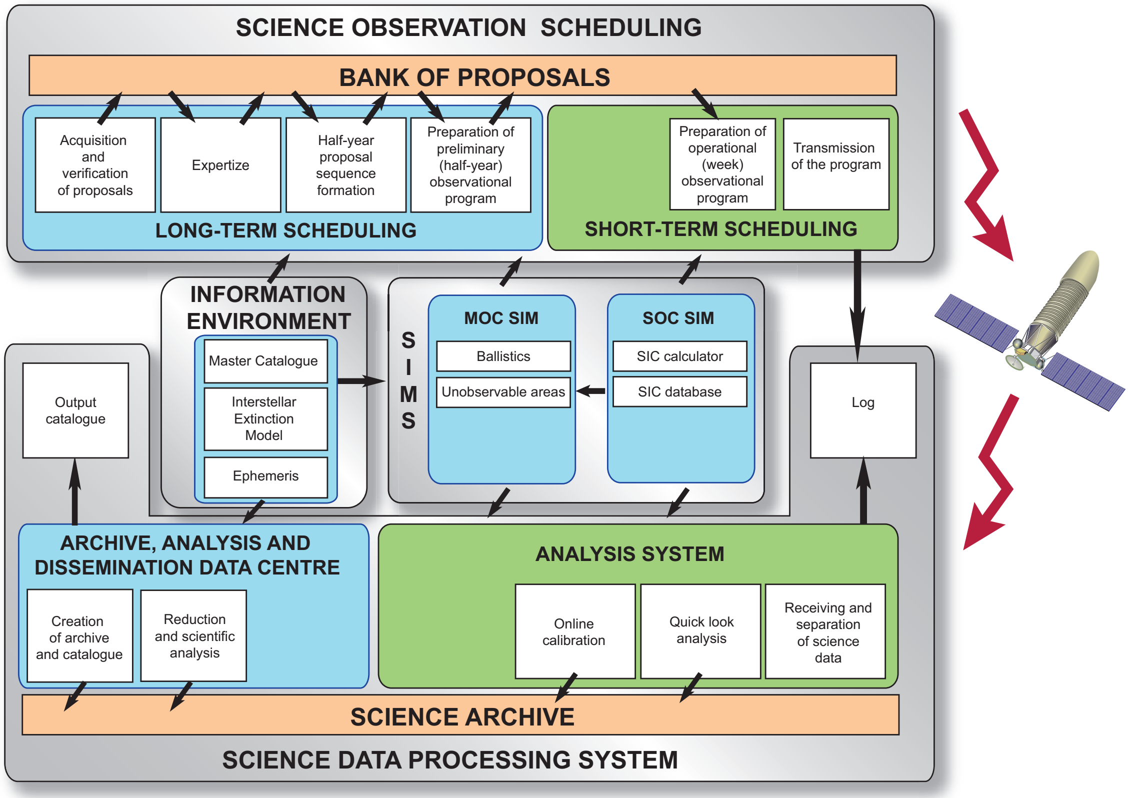

Figure 2: Science Operation Center (current version)

- *Guaranteed time (GT)* allocated to the members of the WSO-UV consortium and will be divided in shares proportional to the financial contribution of the Funding Bodies to the WSO-UV project. GT will be granted to the FBP and CP.
- *Open Time (OT)* allocated to the whole worldwide community. OT will be granted to the OP.
- *Director Discretionary Time (DDT)*, up to a maximum of 2%.
- *Engineering and Calibration Time (ECT)* dedicated to engineering and calibration tests and maintenance. This time will be fixed for each year in advance. It will be set aside from the GT, OT and DDT.

The time for astronomical observations will be distributed according to the following scheme: during *the first year*: 90% GT (distributed in two equal halves between the CP and the FBP), 8% OT, 2% DDT; during *the second and third years*: 70% GT (30% of the total time will be granted to the CP and 40% to the FBP), 28% OT, 2% DDT; for *the following years*: 60% GT (all for the FBP, as the CP shall be completed within the first 3 years of the mission), 38% OT, 2% DDT.

5. Proposals processing

CP Call for Proposals will be issued after preliminary performance of telescope and instruments are known, one year before the launch of the WSO-UV for the whole WSO-UV life. OP and FBP Calls for Proposals will be issued once or twice per year, linked to the whole mission planning lifecycle.

After a collection of proposals from the community Time Allocation Committees will approve a reduce set of proposals. Then detailed proposals will be requested from approved users. Scheduling stages are: construction of a long term program (based on priorities, overall visibility, etc.), construction of a short term programs for one week period, and construction of a per revolution plan for scheduling.

6. Specific proposals and observations

Some specific observations are envisaged, as follows:

- fixed observations, to be only carried out at specific times,
- trigger observations, to be only carried out at specific events,
- pilot observations, to be carried out, and only if successful, it will trigger a chain of next ones,
- linked observations, as sets of observations to be performed jointly.

In case of proposal duplication between two or more programs, FBP will have priority over OP. Duplications of FBPs in the same call are not allowed. Successful teams in two or more FBPs will have to drop the application to all but one FBP.

7. Target of opportunity concept

Two kind of targets of opportunity are considered.

1. Unpredictable targets of opportunity concerning sudden astronomical events, which require immediate observations (e.g., supernova). They will be considered under DDT.

2. Generically predictable targets of opportunity concerning events predictable in a generic case. These include transient phenomena, and follow-up or coordinated observations of targets of special interest. For these targets of opportunity proposals for generic targets will be submitted according to the general rules of CP, FBP and OP. If accepted by the relative committees the program will not be executed until activated by the Principal Investigator after the predicted event has occurred.

Current scenario is based on real-time reaction to target of opportunity alerts. This implies creation of new timeline of commands, interruption of current one and starting of the new one, which will target the spacecraft to the target of opportunity.

8. Optimization of telescope scheduling

Several mathematical tools are being developed to solve the two scheduling optimization problems stated previously (the long-term scheduling problem and the short-term scheduling problem):

from simple greedy or neighbourhood heuristics to the more complex genetic algorithms or neural networks. In [6] the basic scheduling problem was translated into mathematical language, and two main methods were used to solve it: neighbourhood methods and genetic algorithms.

The algorithms are sensitive to the scientific policy by means of the definition of the objective function (i.e., the total scientific weight of the targets scheduled along the horizon time) and by the assignment of priorities to the projects.

Currently, the team is working on a cluster based method to optimize the programming of the observations making use of the observability constraints derived from the spacecraft orbit visibility windows. Also, several tuneable control parameters are been introduced to guaranty the needed degree of flexibility to fit an efficient short-term scheduling within the long-term scheduling.

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References

[1] B. M. Shustov et al. 2009, Astrophys. Space Sci. 320, 187

[2] M. E. Sachkov 2007, AIP Conf. Proc. 938, 148

[3] A. A. Boyarchuk (ed.) *Astrophysical Studies with the "Astron" Space Station*, Nauka, Moscow 1994 (in Russian)

[4] N. Kappelmann, et al. 2006, in *Space Telescopes and Instrumentation II: Ultraviolet to Gamma Ray*, (eds. M. Turner, G. Hasinger), Proc. of the SPIE. 6266, 62660X

[5] M. Huang et al. 2008, in *Space Telescopes and Instrumentation 2008: Ultraviolet to Gamma Ray*, (eds. M. Turner, K. Flanagan), Proc. of the SPIE. 7011, 70111Y

[6] A. I. Gómez de Castro and J. Yáñez 2003, Astron. Astrophys. 403, 357