

# HORUS – THE HIGH ORBIT ULTRAVIOLET-VISIBLE SATELLITE

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## Executive Summary

The High-ORbit Ultraviolet-visible Satellite (*HORUS*) is a 2.4-meter class space telescope that will conduct a comprehensive and systematic study of the astrophysical processes and environments relevant for the births and life cycles of stars and their planetary systems, to investigate and understand the range of environments, feedback mechanisms, and other factors that most affect the outcome of the star and planet formation process.

To do so, *HORUS* will provide 100 times greater imaging efficiency and more than 10 times greater UV spectroscopic sensitivity than has existed on the *Hubble Space Telescope (HST)*. The *HORUS* mission will contribute vital information on how solar systems form and whether habitable planets should be common or rare. It also will investigate the structure, evolution, and destiny of galaxies and universe. This program relies on focused capabilities unique to space that no other planned NASA mission will provide: near-UV/visible (200-1075nm) wide-field, diffraction-limited imaging; and high-sensitivity, high-resolution UV (100-170nm) spectroscopy. Our implementation offers ample opportunity for international participation.

*HORUS* is designed to be launched into a semi-stable orbit at Earth-Sun L2. From this vantage *HORUS* will enjoy a stable environment for thermal and pointing control, and long-duration target visibility. The core *HORUS* design will provide wide field of view (WFOV) imagery and high efficiency point source FUV spectroscopy using a novel combination of spectral selection and field sharing. The *HORUS* Optical Telescope Assembly (OTA) design is based on modern light weight mirror technology with a faster primary mirror to shorten the overall package and thereby reduce mass. The OTA uses a three-mirror anastigmat configuration to provide excellent imagery over a large FOV. The UV/optical Imaging Cameras use two 21k × 21k Focal Plane Arrays (FPAs) consisting of thirty-six Si 3.5k × 3.5k CCD elements each. The FUV spectrometer uses cross strip anode based MCPs improved from *HST-COS* technology. Fine guidance sensing is accomplished via Si arrays mounted at the Cassegrain focus.

We have baselined a total cost for the mission of \$1.28B FY17 including 30% contingency excluding the cost of the launch vehicle, based on a revised cost and technology study conducted at the request of the 2010 Decadal Survey and extrapolated to today. The capabilities and advantages *HORUS* brings to the table are derived from a combination of its aperture, its imaging field of view and its FUV spectral throughput. It could not be done by a MIDEX class mission.

## Science Program

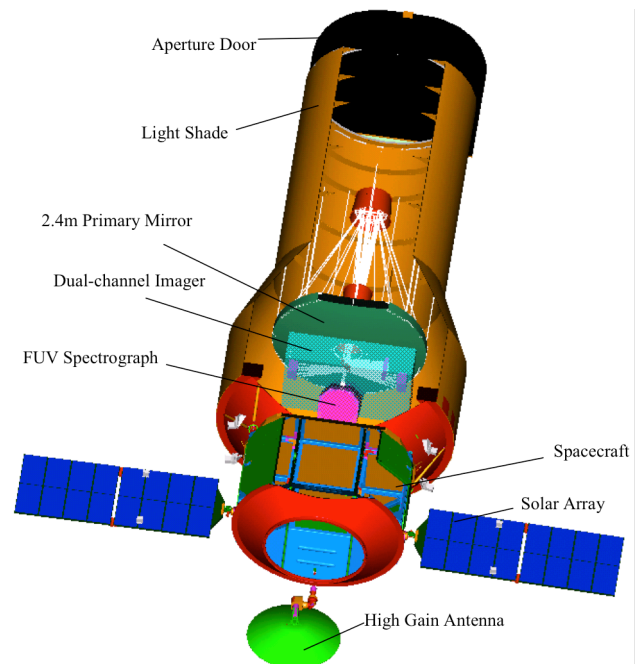
The *HORUS* science program employs a step-wise approach in which both imaging and spectroscopy contribute essential information to our investigation.

Step 1 — Conduct an imaging census of all high-mass star formation sites within 2.5 kpc of the Sun to determine how frequently solar systems form and survive, and develop observational criteria connecting properties of the ionized gas to the underlying stellar population and distribution of protoplanetary disks.

Step 2 — Survey all major star forming regions in the Magellanic Clouds, where we can still resolve relevant physical scales and structures, access starburst analogs, and sample star formation in an initial regime of low metallicity applicable to high-redshift galaxies.

Step 3 — Extend the star formation survey to galaxies in the nearby universe in order to increase the range of galaxy interaction and metallicity environments probed. *HORUS* can observe entire galaxies surveyed by *GALEX* and *Spitzer* with more than 100 times better spatial resolution.

Step 4 — Measure star formation and metal production rates in the distant universe to determine how galaxies assemble and how the elements critical to life such as C and O are generated and distributed through cosmic time.





## Horus Origins Science Mission Fact Sheet

### Overview:

The HORUS Origins Science Mission is a 2.4m UV-visible observatory orbiting at Earth-Sun L2 that will restore on-orbit imaging and UV spectroscopy to the community to allow the pursuit of an aggressive science program to study star and planet formation in visible star-forming environments in the Milky Way, Magellanic Clouds, and both nearby and distant galaxies.

### Science Goals:

1. Characterize global properties and star formation histories in massive star forming regions in the Milky Way.
2. Understand how environment influences the process of star and planet formation.
3. Track the evolution of and derive survivability criteria for low-mass proto-planetary disks in massive star forming regions, similar to where the Solar Nebula likely formed.
4. Spectroscopically detect and characterize extrasolar planets through their UV absorption and emission signatures.
5. Develop a classification scheme for star forming regions based on observable stellar and emission-line diagnostics.
6. Extend the classification scheme to regions that do not have nearby analogs but are common in external galaxies, such as the 30 Doradus region in the Large Magellanic Cloud.
7. Apply the classification scheme to nearby galaxies out to ~5 Mpc to infer the distribution of high- and low-mass star formation over galactic scales.
8. Develop observational criteria (e.g., calibrated H $\alpha$  and [O II] luminosity functions) for characterizing star formation in high-redshift galaxies, where *Spitzer* and *JWST* observe the rest-frame UV-visible emission in the infrared.

### Measurements:

1. Image all massive star forming regions within 2.5 kpc of the Sun through a common set of continuum and emission-line filters with sufficient spatial resolution to distinguish Solar System-scale objects and structures.
2. Identify all exposed proto-planetary disks in nearby massive star forming regions, where most low-mass stars form, and quantify their sizes, orientations, opacities, and distributions.
3. Spectrally search for and identify extrasolar planets as well as infalling cometary material in protostellar systems
4. Survey all massive star forming regions in the Large and Small Magellanic Clouds using the same filter set with sufficient spatial resolution to distinguish structures and processes that have Galactic analogs.
5. Survey a representative sample of Local Group and nearby galaxies – spanning a range of galaxy types, merger histories, and metallicities – using the same filter set with sufficient spatial resolution to distinguish individual star forming sites and internal HII region structure.
6. Extend the scope of the survey to star formation in the distant universe through spectral observations of Ly- $\alpha$  forest hydrogen clouds and quasars

### Performance Requirements and Implementation Summary:

<b>Primary Mirror Diameter:</b>	2.4m (yields ~0.05" resolution at 5000Å)
<b>Image Scale:</b>	Both 0.1 and 0.05 arcsec/pixel (2 imaging modes)
<b>Wavelength Coverage:</b>	200 – 1000 nm (imaging); 100 – 200 nm (spectroscopy)
<b>Field of View:</b>	14' $\times$ 14' (~200 sq-arcmin on 8k $\times$ 8k CCD array; 25 $\times$ HST-WFC3)
<b>Wavelength Multiplexing:</b>	Dichroic split at ~510nm; optimized UV-blue and red-NIR channels
<b>Spectral Capabilities:</b>	100 – 200 nm; R=40,000 over a 0.5" $\times$ 5" slit
<b>Survey Capability:</b>	> 20 sq-degs per yr to surf. brightness of $1 \times 10^{-16}$ ergs/cm <sup>2</sup> /s/arcsec <sup>2</sup>
<b>Optical Design:</b>	Three mirror anastigmat
<b>Pointing/Stabilization:</b>	10 (goal), 20 (core) mas over 1000s (similar to <i>Kepler</i> )
<b>Filter Set:</b>	Broad-band (R~4), medium-band (R~7), narrow-band (R~100)
<b>Detector Efficiency:</b>	CCD DQE: ~80% at 6563Å; ~60% at 3727Å; ~50% in UV
<b>BB Photometry Accuracy:</b>	1% relative, 5% absolute (nominal CCD performance)
<b>Data Volume &amp; Telemetry:</b>	~80 GB per day raw; Ka-band science return (similar to <i>Kepler</i> )
<b>Estimated Mission Cost:</b>	\$1.28B FY17 not including LV, based on Decadal 2010 study extrapolated to today
<b>Launch Vehicle:</b>	Delta IV 3-stage (2925-10L) to L2 orbit
<b>Mission Duration:</b>	3-yr nominal mission (~30 month science phase); 3-yr extended mission

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**Science & Technology Related Missions:** *HST-WFPC2*, *GALEX*, *Spitzer*, *Kepler*, *WISE*, *HST-WFC3*, *JWST*, *WFIRST*