Snowmass2021LOI: Cosmological Synergies Enabled by Joint Analysis of Multi-probe data from The Nancy Grace Roman Space Telescope, Euclid, and the Vera C. Rubin Observatory's Legacy Survey of Space and Time

(CF6) Dark Energy and Cosmic Acceleration: Complementarity of Probes and New Facilities

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Abstract: NASA, NSF, and DOE will collectively spend well over $4B this decade on missions and surveys that have dark energy cosmology as one of their primary drivers. Roman, Euclid, and Rubin are all missions designed to perform dedicated surveys that offer unprecedented statistical constraining power and control of systematic uncertainties. These missions will be significantly more powerful when the data are processed and analyzed in unison. This will require coordinated cross-survey and inter-agency effort. With proper attention to how data are jointly processed and analyzed, the combination of these missions will provide constraints and systematics control that is *better than the sum of their individual parts*. We advocate for international efforts to ensure that the synergy from these multi-probe missions is fully realized.

Pairwise synergies: Many of the synergies arising from joint processing and analysis, a few of which we describe below, are pairwise between the space missions (Euclid and Roman) and Rubin from the ground. Euclid will gather high-resolution optical imaging, lower resolution NIR imaging, and NIR grism spectroscopy over about 2500 square degrees per year for 6 years. At the same time, Rubin will be covering its ~18,000 square degree survey to ever increasing depth. Early Rubin depths will be well matched to the depth of Euclid imaging. In ~2026, Roman's high-resolution NIR imaging and NIR grism spectroscopy will start to be available. The Roman and full Rubin imaging depths will be well-matched in the latter part of the 2020s. Thus, initial joint processing and analysis efforts aimed at the combination of Rubin and Euclid will pave the way for deeper Roman/Rubin data using the same techniques.

Synergistic Measurements: We list here some of the areas of synergistic measurements and that will allow for greater statistical constraining power, more complete control of systematic uncertainties, and most efficient use of resources. See the aforementioned Astro2020 WP for further details.

1. **Object Detection and Deblending**
2. **Photometric Redshift Measurement and Calibration**
3. **Shear Measurement**
4. **Transients and SN**

Some of these measurements will be best made using Derived Data Products (DPP) created from pixel level data from both ground and space based experiments. Euclid and Rubin have addressed this need by creating a Derived Data Products Working Group to recommend DDPs that could be shared with both sets of data rights holders within their respective proprietary periods. Coordination will be needed in the creation of these DDPs and in expanding this effort to include

Roman.

Supercomputing: Euclid, Rubin, and Roman rely on cosmological simulations for their success, and a new paradigm is needed to ensure that the cosmological simulation efforts are being supported in the same way as other key survey infrastructure tasks. These surveys require significant high-performance computing resources for a number of interrelated tasks, including producing numerical simulations, transforming them into synthetic sky maps and simulated images, validating the results, and serving the data to the community in an easily accessible way. Many of the tasks are common between the major cosmological surveys and it is therefore strongly advisable to evaluate common approaches and inter-project resource sharing. NASA has taken some first, funded substantive steps toward coordination of sharing cosmological simulations results across Rubin/Roman/Euclid. This NASA-funded effort is currently working to generate an optimized pipeline for producing simulated extragalactic catalogs and develop optimized image simulation capabilities that are usable across Roman, Rubin, and Euclid. In addition, to maximize the science output from the simulated data products, a curation approach for archiving and serving the simulated data to the broader scientific community is being developed. All relevant funding agencies and projects should be encouraged to work together to identify the areas where each can meaningfully contribute to a coordinated effort of this nature.

Addressing tensions with multiple probes: Recent measurements of the growth of cosmic structure made by weak lensing are, taken as a set, possibly in tension with the Planck constraints on a ΛCDM cosmology. Supernova measurements of the Hubble constant that rely on the determination of distances in the local universe are in somewhat stronger tension with those that rely on the determination of the scale of the sound horizon in the CMB. There is no consensus on whether these tensions should be seen as statistical flukes, attributed to systematic errors in one or more of the measurements, or hints of extensions to the consensus model. With Stage IV data, these tensions may grow or vanish in significance. However, they are precisely the sort of signatures of new physics that the next generation of cosmological probes hopes to find.

The current lack of a consensus interpretation of these tensions can be attributed in part to the complexity of the measurements themselves and in part to the lack of tools and methods for rigorously probing the nature of disagreement between these kinds of measurements at sufficient precision. The global cosmology community should be coordinated in addressing this latter concern. To do this, we should maximize the exposure of potential sources of systematic error in one survey to measurement in others, invest in resources that allow us to trace disagreement in the space of high-level parameters back to primitive elements of the underlying data vector, and take full advantage of overlapping survey footprints that allow us to ensure that similar experiments are seeing appropriately similar underlying skies.

Final Recommendation: While each of the major cosmological experiments of the 2020s should first make its own stand-alone measurements, the ultimate result will be more than the sum of the parts if the community has the resources and direction to properly coordinate the joint processing and analysis. The appropriate US agencies should work with our international partners to see that this is made a reality, and to share high-performance computing resources and products across surveys.