

The Vera C. Rubin Observatory Data Preview 2

VERA C. RUBIN OBSERVATORY TEAM,¹ ERIC C. BELL¹,² PEDRO H. BERNARDINELLI¹,³ AUDREY BUDLONG¹,⁴ NEVEN CAPLAR¹,² COLIN ORION CHANDLER¹,^{5,2,6} JOHANN COHEN-TANUGI¹,⁷ CYRILLE DOUX¹,⁸ SIEGFRIED EGGL¹,⁹ ANTHONY ENGLERT¹,¹⁰ MELISSA L. GRAHAM¹,^{2,3} LEANNE P. GUY¹,¹¹ MATTHEW J. HOLMAN¹,¹² MINHEE HYUN¹,¹³ MARIO JURIC¹,³ YIJUNG KANG¹,^{14,11} ARUN KANNAWADI¹,^{15,16} KSHITIJ KELKAR¹,¹¹ SHUANG LIANG,¹⁷ KIAN-TAT LIM¹,¹⁷ SAMUEL MESQUITA¹,⁸ JAMES R. MULLANEY¹,¹⁸ KATE NAPIER¹,¹⁴ WILLIAM O’MULLANE¹,¹¹ AASHAY PAI¹,¹⁹ KARLA PEÑA RAMÍREZ¹,¹¹ ANDRÉS A. PLAZAS MALAGÓN¹,^{17,14} AND IAN S. SULLIVAN¹,²

¹NSF-DOE Vera C. Rubin Observatory / NSF NOIRLab, 950 N. Cherry Ave., Tucson, AZ 85719, USA

²University of Washington, Dept. of Astronomy, Box 351580, Seattle, WA 98195, USA

³Institute for Data-intensive Research in Astrophysics and Cosmology, University of Washington, 3910 15th Avenue NE, Seattle, WA 98195, USA

⁴University of Washington, Dept. of Physics, Box 351580, Seattle, WA 98195, USA

⁵LSST Interdisciplinary Network for Collaboration and Computing, Tucson, USA

⁶Department of Astronomy and Planetary Science, Northern Arizona University, P.O. Box 6010, Flagstaff, AZ 86011, USA

⁷LPCA, Université Clermont-Auvergne, CNRS/IN2P3, Clermont-Ferrand, France

⁸Université Grenoble Alpes, CNRS/IN2P3, LPSC, 53 avenue des Martyrs, F-38026 Grenoble, France

⁹University of Illinois, Department of Astronomy, 1110 W. Green St., Urbana, IL 61801, USA

¹⁰Department of Physics, Brown University, 182 Hope Street, Providence, RI 02912, USA

¹¹NSF-DOE Vera C. Rubin Observatory / NSF NOIRLab, Casilla 603, La Serena, Chile

¹²Center for Astrophysics, Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138

¹³Stanford University, 450 Jane Stanford Way, Stanford, CA 94305, USA

¹⁴Kavli Institute for Particle Astrophysics and Cosmology, SLAC National Accelerator Laboratory, 2575 Sand Hill Rd., Menlo Park, CA 94025, USA

¹⁵Department of Physics, Duke University, Durham, NC 27708, USA

¹⁶Department of Astrophysical Sciences, Princeton University, Princeton, NJ 08544, USA

¹⁷SLAC National Accelerator Laboratory, 2575 Sand Hill Rd., Menlo Park, CA 94025, USA

¹⁸Astrophysics Research Cluster, School of Mathematical and Physical Sciences, University of Sheffield, Sheffield, S3 7RH, United Kingdom

¹⁹Department of Astronomy and Astrophysics, University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637, USA

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ABSTRACT

We present an early version of Rubin Data Preview 2 (DP2), the second data preview from the National Science Foundation–Department of Energy Vera C. Rubin Observatory. **Early Data Preview 2 (EDP2)** comprises coadds, detection catalogs, and ancillary data products; eventually, the full DP2 will also include single-epoch images and difference images. DP2 is derived from observations acquired by the LSST Science Camera (LSSTCam) on the Simonyi Survey Telescope at the Summit Facility on Cerro Pachón, Chile, primarily during the on-sky commissioning campaign between 2025-04-16 and 2025-09-21, supplemented by observations taken between 2025-10-25 and 2026-01-06 that overlap the commissioning footprint. The DP2 footprint comprises the Science Validation wide-area survey, five Deep Drilling Fields, and a number of targeted small-field regions, including Trifid and Lagoon, Prawn, M49, and New Horizons, all observed as part of the Rubin First Look campaign. Each field was imaged in up to six broad photometric bands, *ugrizy*, and coadded to produce deep imaging covering an estimated 3,000 deg². The addition of single-visit-only areas expands the total DP2 footprint to an estimated 15,000 deg², with coverage in at least one filter. The median per-visit PSF FWHM across the wide-area survey ranges from 1.17 arcsec in the *z* band to 1.26 arcsec in *g* and *r* bands, with the sharpest fields reaching $\sim 0''.0$. COSMOS, the deepest field, reaches estimated coadded 5σ

depths of $u=26$ mag, $g=26.8$ mag, $r=26.3$ mag, $i=26.1$ mag, $z=25.3$ mag, $y=23.9$ mag. DP2 contains X distinct astrophysical objects, of which X are extended in at least one band in coadds, and X solar system objects, of which X are new discoveries. DP2 is approximately 59.15 TB in size and is available to Vera C. Rubin Observatory data rights holders via the Rubin Science Platform, a cloud-based environment for the analysis of petascale astronomical data. Based on a roughly five-month primary observing baseline and covering only part of the eventual LSST footprint, DP2’s area, depth, and multiband coverage nonetheless support a broad range of early science investigations ahead of LSST Data Release 1.

Keywords: Rubin Observatory - LSST

1. INTRODUCTION

The National Science Foundation (NSF)–Department of Energy (DOE) Vera C. Rubin Observatory is a ground-based, wide-field optical-near-infrared facility on Cerro Pachón in northern Chile, built to carry out the Legacy Survey of Space and Time (LSST) (Ivezić et al. 2019). The observatory is named in honor of Vera C. Rubin, whose observations in the latter half of the 20th century established the first compelling empirical case for dark matter (Rubin & Ford 1970; Rubin et al. 1980). Its 10-yr survey will image the entire visible southern sky every 3–4 nights, reaching a coadded depth of ~ 27 mag in the r -band across an 18000 deg² footprint (Bianco et al. 2022).

At the heart of the facility is the 3.2 gigapixels-gigapixel LSST Science Camera (LSSTCam), mounted on the 8.4 m (6.5 m effective aperture) Simonyi Survey Telescope (Stalder et al. 2024). Together they deliver an instantaneous field of view of 9.6 deg² in six broadband filters, *ugrizy* (320–1050 nm), with seeing-limited image quality. The system’s étendue of 319 deg² m² exceeds that of any previous optical facility by over an order of magnitude, enabling the rapid, deep, all-sky cadence that underpins Rubin’s four core science themes: the nature of dark energy and dark matter; a census of the solar system; the transient and variable optical sky; and the structure of the Milky Way (Ivezić et al. 2019). An automated Data Management System processes tens of terabytes of images per night to produce science-ready data products within minutes of each observation for a global community of scientists.

This paper presents Rubin’s third Data Preview, Data Preview 2 (DP2) (NSF-DOE Vera C. Rubin Observatory 2025), and the first to be based entirely on LSSTCam data. It marks the conclusion of the Rubin commissioning program and the transition to full survey operations. DP2 is a reprocessing of all science-grade exposures acquired with LSSTCam during on-sky commissioning and the initial phase of early operations, prior to the formal start of the LSST on 2026-06-29. As such, it represents a

natural boundary and provides a comprehensive dataset that captures the on-sky performance of the as-built system at the end of the Rubin construction project.

Two earlier Data Previews preceded DP2 as part of the Rubin Early Science Program (Guy et al. 2026), established to provide the community with early access to data products and services needed to produce high-impact science during the period spanning commissioning through the first Data Release. Data Preview 0 (DP0) was based on simulated LSST-like data (LSST Dark Energy Science Collaboration (LSST DESC) et al. 2021) and served primarily to stand up early versions of the Rubin Science Platform (RSP) and prepare the community for data access at scale. Data Preview 1 (DP1) (NSF-DOE Vera C. Rubin Observatory 2025) delivered the first data products derived from on-sky observations using science-grade exposures acquired with Rubin Commissioning Camera (LSSTComCam) (Stalder et al. 2022, 2020; Howard et al. 2018; SLAC National Accelerator Laboratory & NSF-DOE Vera C. Rubin Observatory 2024); a 144-megapixel, single-raft instrument used during early commissioning prior to the installation of LSSTCam on the Simonyi Survey Telescope. DP2 supersedes both in scope, fidelity, and scientific depth.

DP2 contains X science-grade exposures acquired over 158 nights between 2025-04-16 and 2025-09-21, covering a total sky area of ~ 15 deg² across X fields. The data products include raw and calibrated single-epoch images, coadded images, difference images, source detection catalogs, and a range of derived data products. The release totals approximately 59.15 TB and contains around X distinct astronomical objects. Full release documentation is available at <https://dp2.lsst.io>.

Because DP2 is drawn from a commissioning and early-operations data rather than from the more uniform and systematic LSST, its images and derived products reflect a system that was still being commissioned and tuned. LSSTCam’s greater scale and complexity relative to LSSTComCam introduced systematics with no direct counterpart in DP1. For much of the campaign

the [Active Optics System \(AOS\)](#) closed loop converged on a slightly mis-calibrated focus target, imprinting a spatially varying defocus across the focal plane that was only corrected on sky in December 2025 and that remains visible in the point-spread function (PSF) of a large fraction of [DP2](#) exposures. Delivered image quality and PSF ellipticity did not consistently meet [LSST](#) design requirements in wide-area survey-mode observations by the close of commissioning; and stray- and scattered-light artifacts, sky-background systematics in crowded fields, and a chromatic PSF dependence²⁰ were identified and only partially mitigated in [DP2](#) processing. These effects, their diagnosis, and the mitigations applied are described in [§2](#) and [§5](#).

Unlike the systematic, rolling revisit pattern that will characterize the [LSST](#), [DP2](#)’s observing cadence is opportunistic: fields and filters were prioritized to serve [AOS](#) and Science Pipelines commissioning rather than to build a representative time series. The Science Validation survey footprint was repeatedly re-scoped over the course of the science validation campaign due to the competing demands of engineering tests and filter availability, which was constrained by hardware issues for part of the campaign. Visit counts and time sampling therefore vary substantially and idiosyncratically from field to field, and [DP2](#) should not be read as a preview of [LSST](#)’s eventual survey cadence, revisit statistics, or depth-accumulation pattern.

[DP2](#) is being delivered in two phases across the Jul–Dec 2026 window. The first phase, Early [DP2](#) (EDP2), comprises the deep coadd images and all associated catalogs, including new cell-based coadds and the first releases of the Object Shear (§??) shape-measurement catalog and the Isolated Star Stellar Motions catalog (§??). EDP2 is targeted for 2026-07-27. The second phase, [DP2](#), adds the visit-level single-epoch and difference images, completing the full release, and is expected in the Oct–Dec 2026 range. Data products delivered as [EDP2](#) will be incorporated into [DP2](#) unchanged, without additional reprocessing ([Guy et al. 2026](#)). This phased delivery follows directly from Rubin’s hybrid cloud architecture ([O’Mullane et al. 2024](#)), in which science data products are stored at the [United States Data Facility \(USDF\)](#) and served to users via the [US Data Access Center \(DAC\)](#) in Google Cloud. Deep coadd images and catalogs are hosted directly in Google Cloud and are therefore unaffected by hybrid-cloud readiness, allowing them to ship as [EDP2](#). Visit-level images, however, must be streamed from the [USDF](#), and the necessary capacity is

not yet fully in place, introducing timing uncertainty for the second phase. Delivery of the Prompt Data Products follows the same logic. The [Prompt Products DataBase \(PPDB\)](#), Rubin’s real-time catalog of transient, variable, and moving-object detections, does not depend on [USDF](#)–Google Cloud bandwidth and is therefore prioritized as the second Early-Operations delivery milestone, following EDP2 and preceding the full [DP2](#) release, expected in the Sep–Oct 2026 range. Prompt images (raw images, Processed Visit Images, and difference images), which do require that bandwidth, have been deprioritized relative to EDP2 and the [PPDB](#) and are expected to become available only in the Oct–Dec 2026 range, following both.

[DP2](#), like all Rubin Data Previews and Data Releases, is subject to a 2 yr proprietary period; during this time access is restricted to [LSST](#) data rights holders ([Blum & the Rubin Operations Team 2020](#)) via the [RSP](#) ([Jurić et al. 2019](#)), Rubin’s cloud-based data science platform ([Jurić et al. 2019](#)). After the proprietary period, [DP2](#) will be made public, though access through Rubin [DACs](#) in the US and Chile will remain limited to data rights holders ([Blum & the Rubin Operations Team 2020](#)). Alternative public access mechanisms have not yet been finalized.

The structure of this paper is as follows. Section 2 describes the observatory system and its status at the close of commissioning, the fields included in [DP2](#), and the observing strategy employed. Section 3 summarizes the data products in the release. The processing pipelines are described in Section 4, followed by data validation and performance characterization in Section 5. Section 6 describes the [RSP](#). Section 7 outlines Rubin’s community support model. A summary and outlook toward the start of formal [LSST](#) Data Releases is given in Section 8.

All magnitudes are quoted in the AB system ([Oke & Gunn 1983](#)) unless otherwise specified.

2. COMMISSIONING WITH LSSTCAM

3. OVERVIEW OF THE CONTENTS OF RUBIN DP2

4. DATA RELEASE PROCESSING

5. PERFORMANCE CHARACTERIZATION AND KNOWN ISSUES

Look at the science requirements document. [ls.st/srd](#), [ls.st/lst](#), [ls.st/oss](#), [ls.st/dmsr](#).

This [DP2](#) paper should give a good indication of what we expect for [LSST](#) proper.

The following subsection headers are placeholders.

In the following, groups of three numbers in brackets correspond to (design, minimum, stretch).

²⁰ [LSSTCam](#) has no atmospheric dispersion corrector

5.1. *Visit-level*

5.1.1. *Filter compliment*

See SRD.

5.1.2. *PVI Depth*

Median point source r-band 5sigma depth of D1 mag, where $D1=(24.7, 24.3, 24.8)$.

No more than DF1 per cent of images will have point source r-band 5sigma depths greater than Z1, where $DF=(10, 20, 5)$ and $z=(24.4, 24.2, 24.6)$.

D1 for all bands are:

- u: (23.9, 23.4, 24.0)
- g: (25.0, 24.6, 24.3)
- r: (24.7, 24.3, 24.8)
- i: (24.0, 23.6, 24.1)
- z: (23.3, 22.9, 23.4)
- y: (22.1, 21.7, 22.2)

Put the above comparison in a table (table 1?).

Variation in depth across the FOV:

For a median-depth visit, no more than DF2 per cent of detector-images will have a 5sigma point source depth brighter than Z2, where $DF2=(15, 20, 10)$ and $Z2=(0.2, 0.4, 0.2)$. This should be in a section, not (necessarily) in a table.

May also want to include an estimate of the saturation limit (in magnitudes) in this subsection.

5.1.3. *Image quality*

Note that image quality improved over commissioning (DP2). Take a late-stage subset, or perhaps a curated late-stage subset that we can argue would be representative of what we expect going forward.

5.1.4. *PSF accuracy*

A full analysis of the PSF characterization of the Rubin Observatory data is currently being written (Léget et al. 2026), so here we present only the key findings. One of the key findings is that the PSF shape correlates with variations in height across the focal plane (see Lalot et al. 2026 for more details). This explains why ITL sensors, which exhibit a curved shape, are more difficult to model than E2V’s flat sensors, and why a fourth-order model is justified, as noted previously in the DP1 paper. As described in Pai et al. (2026), the LSST-Cam PSF is chromatic (i.e., wavelength-dependent) and appears to be compatible with *Differential Chromatic Refraction* (DCR). As shown in Pai et al. (2026), we are

able to model it in the same spirit as the DES Y6 PSF analysis, but this was not enabled during DP2 processing because the connections to the downstream processes were not in place. In addition, DP2 has an order of magnitude more visits than previous processing campaigns, revealing a new variety of PSF-related issues, including annealing patterns in E2V sensors — visible in the u- and g-band stacks — and fringing in the z- and y-bands. All are expected to arise from background subtraction. Moreover, PSF residuals in DP2 show structure that correlates with stellar density, with the largest biases appearing in the plane of the Milky Way, the LMC, and the SMC. This stellar-density dependence also explains the observed differences in PSF residuals between bands, since more crowded bands show larger residuals. The underlying cause is again believed to be related to background subtraction in dense fields.

5.1.5. *Astrometric accuracy*

5.1.6. *Photometric accuracy*

5.2. *Coadd-level*

5.3. *Prediction for 10-year survey*

Details of calculation should go in a separate paper. This section should probably be just two or three paragraphs, depending on what parameters we want to predict.

5.4. *Crowded Fields*

Crowded fields represent a key challenge for the LSST Science Pipelines, pushing the current limits of source detection, deblending, and photometry. They are defined as regions in which the stellar source density exceeds the resolving capability of current algorithms. In such regions, the pipeline produces large, contiguous detection footprints encompassing multiple astrophysical sources rather than assigning distinct footprints to individual objects; the corresponding pixels are flagged as `NOT_DEBLENDED`. We therefore use the proportion of pixels flagged as `NOT_DEBLENDED` as a proxy for the area of the survey that is associated with crowded fields.

Overall, out of the 2.2 trillion pixels comprising the total DP2 sky area, 12.9% are associated with crowded fields via the aforementioned definition. This fraction, however, obscures the highly localized nature of crowded fields within the survey. Specifically, 1,750 of 2,174 total tracts (i.e., 80.5%) have less than 1% of their pixels flagged as `NOT_DEBLENDED`. Of the remaining 424 (i.e., 19.5%) tracts, 90% are found within 14.5 degrees of the Galactic plane where the stellar densities are the highest. These regions therefore account for the majority of the survey’s crowded-field processing challenges.

As the survey continues, crowded fields will comprise an increasingly large fraction of the observed sky. Robust processing of these fields is therefore essential to fully realizing the scientific goals of LSST. To address this challenge, a dedicated crowded-field processing pipeline is currently under development. Early results are promising: regions that appear as merged detections in the standard pipeline can instead be successfully deblended into their constituent sources, enabling individual detection and measurement. The pipeline is currently undergoing testing, with integration into the LSST Science Pipelines for general use targeted within the next year.

6. RUBIN SCIENCE PLATFORM

7. SUPPORT FOR COMMUNITY SCIENCE

Rubin Observatory’s model to support its large, diverse science community to access and analyze DP2 focuses on providing documentation, tutorials, and live virtual learning opportunities alongside an open platform for issue reporting and resolution that enables crowd-sourced solutions. These support resources are all available via the main hub of Rubin’s “For Scientists” website²¹.

The data release documentation for DP2²² provides an overview of the LSSTCam observations, data quality summary plots, and descriptions of the contents and access methods for all catalog and image datasets. All tutorials (NSF-DOE Vera C. Rubin Observatory 2021) that demonstrate DP2 access via the Rubin Science Platform are delivered in the data release documentation, and executable versions of the Jupyter notebook tutorials are also available from a drop-down menu within the Notebook Aspect.

Early DP2 was released on the first day of the annual Rubin Community Workshop, July 27 2026. A dedicated “Get started with DP2” session was added to the Wednesday agenda. Four DP2-onboarding virtual sessions were run in the first week of August, a mix of presentations, tutorials, and time for issue resolution.

The Rubin Community Forum²³ is the open platform for user issue reporting and resolution. Rubin staff monitor all new topics posted in the Support category and ensure that all requests for help get a response and a solution. The open nature of the platform also enables peer-to-peer support that avoids knowledge bottlenecks and hastens the time to resolution.

8. SUMMARY AND FUTURE RELEASES

DP2 provides the first release of science-grade data products from the LSSTCam focal plane. As for DP1, DP2 is part of Rubin’s Early Science Program (Guy et al. 2026) and carries a 2 yr proprietary period during which access is restricted to LSST data rights holders via the cloud-based RSP.

DP2 is delivered in two phases: Early DP2 (EDP2), which provides deep coadded images, all science catalogs, and ancillary data products including throughput curves, survey property maps, and calibration products; and DP2, planned for late 2026, which adds visit-level and difference-image data products to complete the release. The coadded images and catalogs delivered in EDP2 will not be reprocessed for DP2; the data are unchanged, and DP2 supersedes and fully encompasses EDP2 by adding the remaining products to the same release. Analyses begun on EDP2 products require no modification.

DP2 represents a substantial advance relative to DP1: the full LSSTCam focal plane replaces the single-raft LSSTComCam, all six *ugrizy* filters are available in place of three, and the sky area is larger by approximately two orders of magnitude. Nevertheless, DP2 reflects the state of an observatory still in the process of optimization: delivered image quality had not yet consistently reached design specification, template coverage is incomplete across the full sky, and several pipeline components remain under active development. Users are encouraged to consult the release documentation at <https://dp2.lsst.io> and the known issues register maintained there before beginning scientific analyses.

The body of science-grade LSSTCam data acquired between the end of the DP2 observing window on 2026-01-06 and the formal start of the LSST on 2026-06-29 will be processed and made available to LSST data rights holders through the same RSP services. The format and timing of this release are still under discussion; planning will be finalised once DP2 has been delivered.

The first LSST Data Release, Data Release 1 (DR1), will be derived from a reprocessing of approximately the first year of LSST survey data and is currently expected in mid-2028; its precise definition remains under consideration. DR1 will mark a qualitative advance beyond DP2: observations collected under the community-developed baseline survey strategy (Rubin’s Survey Cadence Optimization Committee et al. 2022, 2023, 2025; The Rubin Observatory Survey Cadence Optimization Committee 2026) will yield substantially broader and more uniform sky coverage across the full Wide-Fast-Deep (WFD) footprint of 18000 deg², a balanced six-band filter distribution, and improved deliv-

²¹ <https://rubinobservatory.org/for-scientists>

²² <https://dp2.lsst.io>

²³ <https://community.lsst.org/>

ered image quality as [AOS](#) and dome thermal management continue to mature ([NSF-DOE Vera C. Rubin Observatory 2026](#)). Photometric and astrometric calibration will benefit from a full year of all-sky coverage, difference-imaging templates will span a far greater fraction of the footprint and processing will draw on a more mature version of the [LSST Science Pipelines](#) refined through [DP2](#) experience and community engagement. Subsequent [LSST Data Releases](#) are planned at an approximately yearly cadence, each a complete reprocessing of all survey data accumulated to that point, with progressively deeper coadds and improved calibration. Plans will be updated through revisions to [Guy et al. \(2026\)](#) and on the Rubin community forum at <https://community.lsst.org>.

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Facilities: Rubin:Simonyi (LSSTComCam), Rubin:USDAC

Software: Rubin Data Butler ([Jenness et al. 2022](#)), LSST Science Pipelines ([Rubin Observatory Science Pipelines Developers 2025](#)), LSST Feature Based Scheduler v3.0 ([Jones 2026](#)) Astropy ([Astropy Collaboration et al. 2013, 2018, 2022](#)) PIFF ([Jarvis et al. 2021](#)), GBDES ([Bernstein 2022](#)), Qserv ([Wang et al. 2011; Mueller et al. 2025](#)), Slurm, HTCondor, CVMFS, FTS3, ESNet

APPENDIX

Glossary

AOS: Active Optics System.

AURA: Association of Universities for Research in Astronomy.

DAC: Data Access Center.

Data Management System: The computing infrastructure, middleware, and applications that process, store, and enable information extraction from the LSST dataset; the DMS will process petascale data volume, convert raw images into a faithful representation of the universe, and archive the results in a useful form. The infrastructure layer consists of the computing, storage, networking hardware, and system software. The middleware layer handles distributed processing, data access, user interface, and system operations services. The applications layer includes the data pipelines and the science data archives’ products and services.

DCR: Differential Chromatic Refraction.

DOE: Department of Energy.

DP0: Data Preview 0.

DP1: Data Preview 1.

DP2: Data Preview 2.

DR1: Data Release 1.

EDP2: Early Data Preview 2.

LSST: Legacy Survey of Space and Time.

LSSTCam: LSST Science Camera.

LSSTComCam: Rubin Commissioning Camera.

NSF: National Science Foundation.

PPDB: Prompt Products DataBase.

RSP: Rubin Science Platform.

USDF: United States Data Facility.

WFD: Wide-Fast-Deep.

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