Sample Conservation Plan for the NASA OSIRIS-REx Collection

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1. GOALS OF THIS PLAN

The goal of this curation conservation plan is to define a schema to balance allocation of OSIRIS-REx samples for contemporary scientific research with long-term preservation of pristine samples for future scientific study. This plan begins with the early curation of the collection after Earth return, coincident with the sample-analysis phase of the mission, denoted as year 1 and year 2. The OSIRIS-REx sample curation catalog will include Bennu asteroid samples, witness plates, contact pads and associated particles, and hardware items from the sample return capsule. Henceforth, this will be referred to as the "curation catalog." The curation catalog will be first published half-way through year 1, at which point the JSC Astromaterials Acquisition & Curation Office (henceforth "Curation") will accept sample requests from the scientific community. The requests will be evaluated by an allocation review board, following the Charter for NASA's Astromaterials Allocation Review Board (AARB), that intends to first meet in the summer of 2024. This plan will be considered both during the review process and by Curation in making allocation decisions.

2. COLLECTION

The OSIRIS-REx returned-sample collection includes both returned asteroid sample and flight hardware. Most of the asteroid sample was inside the head of the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) upon collection (Lauretta et al. 2017, Bierhaus et al. 2018), and is comprised of a broad range of particle sizes from as large as a few centimeters to less than a micrometer. The OSIRIS-REx "bulk sample" includes asteroid material that is returned to Earth inside of the TAGSAM head and within the TAGSAM capture ring located on the avionics deck of the Sample Return Capsule (SRC). In addition, asteroid material is present on the flight hardware, including the contact pads, the screens on the witness plates, and wedged into or adhering to hardware items, as expected (Lauretta et al. 2017, Bierhaus et al. 2018, Dworkin et al. 2018, Lauretta et al. 2022).

3. SCOPE OF THE CONSERVATION PLAN

This plan applies to the bulk sample as a whole, but also to distinct lithologies identified during preliminary examination (PE) or in the course of future research on the collection. In addition, this conservation plan applies to "special" samples or the restricted access collection (RAC), which are synonyms in this collection. Special/RAC samples will be treated as distinct lithologies, thus percentage-based allocation restrictions will be allied to each individually– for example, only 25% of each "special" sample may be allocated to the mission sample analysis team (SAT) as a regular mission allocation.

4. DEFINITION OF PRISTINITY FOR OSIRIS-REX ASTEROID SAMPLES

Curation defines pristine samples as those that have been continuously maintained in the curation environment after being received at NASA's Johnson Space Center. For OSIRIS-REx, pristine samples will be maintained in an anoxic nitrogen (N_2) atmosphere, in positive pressure

gloveboxes with N_2 flow or sealed containers stored in desiccators with N_2 atmospheres. The N_2 gas to which pristine samples are exposed is directly controlled and monitored by NASA Curation. In addition, pristine samples will only encounter approved materials (curation compliant materials defined in Appendix A and a limited number of additional materials with official waivers). Prior and during the sample analysis phase of the OSIRIS-REx mission, the wavier processes requires a review of the items requested for a waiver, potential impact on the collection, and justification of the requested waiver. A waiver for a material is only approved/granted through signed written memos from the mission contamination control officer, Astromaterials Research and Exploration Science (ARES) contamination control officer, and the OSIRIS-REx sample curator. After completion of the sample analysis phase of the OSIRIS-REx mission, approval from the mission contamination control officer will no longer be required.

All allocated samples that leave the JSC curation facility will be considered non-pristine, unless a special plan is approved prior to allocation to maintain pristinity. This acceptance that allocated samples will be no longer pristine includes all allocations to the OSIRIS-REx mission sample analysis team (SAT) (up to 25% of the returned bulk sample), to the broader science community, and samples allocated for public display.

Certain types of allocations and curation processes will affect the pristinity of some non-allocated material. The pristinity of samples is tracked in the OSIRIS-REx flight database; the pristinity state of samples (or pieces of a sample) is documented in their sample inventory record in the OSIRIS-REx flight curation database coincident with activities that render them no longer pristine. Once a sample or part of a sample is no longer pristine it remains no longer pristine for perpetuity and will be stored in a non-pristine glovebox box or desiccator. A small percentage of the bulk sample will be rendered non-pristine for preparation of catalog updates. Preparation of thin and/or polished sections will render both the sections and any remaining unpolished material non-pristine. In making allocation decisions, the effect of sample preparation on both allocated and non-allocated material will be considered.

OSIRIS-REx asteroid samples will be considered curation pristine if they are X-ray computed tomography (XCT) scanned onsite at JSC in curation-designed tri-clamp-viton-gasket sealed XCT sample containers and returned to the OREx curation lab (room 216) within five days of leaving the gloveboxes/nitrogen desiccators. Each sample that is XCT scanned will include that information under its sample history in the curation database and in the public catalog. In addition, ~25% by mass of characterized material from any recognized lithology of particles larger than 5 mm in one dimension will not be XCT scanned in case future studies reveal XCT scanning is more damaging than currently understood. Curation may elect to XCT scan particles prior to allocation for destructive analyses, in cases when the proposed measurements are not anticipated to be negatively impacted by x-ray exposure. The OSIRIS-REx sample request form provides a field for requesters to communicate to the panel and curation if the proposed measurements could be impacted by XCT scanning prior to allocation.

5. APPLICATION OF THE CONSERVATION PLAN

The conservation plan does not apply to transfers made to international partners of the OSIRIS-REx mission (4.5% of the returned bulk sample). These samples are considered to be separately conserved by the recipient partner countries (Japan and Canada). The initial NASA pristine masses of all samples will be determined after removal of material for these partners.

The catalog shall provide information to requestors about the amount of pristine sample remaining, and the amount that may be requested at the current time (for rolling application deadlines) or at the application deadline (for fixed request deadlines). Allocation limits due to pristinity (or other factors) are always based on the time of request, not on the anticipated time of allocation.

6. STATE OF THE COLLECTION AT THE TIME OF PUBLICATION OF THE INITIAL CATALOG DURING YEAR 1

6.1 Bulk Sample

All the returned asteroid material was considered pristine upon opening the sample canister in the curation glovebox at JSC. At this point, the OSIRIS-REx returned sample collection from within the canister was 100% pristine. The "returned bulk sample" designates all loose material collected from the SRC. The "NASA bulk sample" designates the portion of the returned bulk sample not allocated to international partners (even if not yet separated from the returned bulk sample). The initial steps for PE were designed to maintain the pristinity of the returned bulk sample until it has undergone basic characterization (e.g., weight, macroscopic description, and photographic documentation).

Up to 25.5% of the bulk sample may be rendered non-pristine due to planned curatorial and science-team activities during PE, as shown in Table 1. This includes up to four early OSIRIS-REx public display samples to be exhibited shortly after Earth return (at the Smithsonian Institution, University of Arizona museum, Space Center Houston, and a display sample for short-term loans by the Agency). The early public display samples are not part of the SAT allocation. These early public display samples have a combined mass limit of 0.5 wt. % of the bulk sample.

Table 1: Pristinity of NASA Bulk Sample expected at the time of initial catalog publication

Separate/s	Long-term Pristine?	% of Returned Bulk Sample
White Sands Complex (WSC)	Yes	10.0
Hermetically Sealed (HS)	Yes	2.5
Frozen	Yes	5.0
Public Display Samples	No	0.5
Sample Analysis Team (SAT)[a]	No	25.0
Maximum non-pristine at time of initial catalog publication		**25.5**

6.2 Contact Pads

The TAGSAM head fully contacted and sank into the surface of Bennu during TAG. Thus, up to 25% of the sample on the contact pads may be rendered non-pristine due to SAT activities. There were 24 contact pads on the bottom of the TAGSAM head. By international agreements, one contact pad will be transferred to Canada and one contact pad will be transferred to Japan. For the first catalog release, curation images of the contact pads will be included but individual contact pad particles will not be available for request by the broader scientific community because curation catalog development efforts focused on processing bulk samples. The particles on the contact pads are difficult and time consuming to process (remove and containerize) in a curation glovebox. After curation processing of the contact pads begins, individual particles/samples from the contact pads will be included in subsequent catalog updates. The first individual particles from contact pads are anticipated to be added in the spring 2025 catalog update. These particles will be too small to determine reliable masses for inside of a glovebox. In addition, the SAT may be allocated an entire contact pad with particles that was not previously processed by curation. Curation does not anticipate allocating entire contact pads to the broader scientific community as a common practice, therefore, requests for an entire contact pad will be treated as a request for material from a restricted access collection (RAC) sample.

6.3 Flight Witness Plate Materials

The flight witness plates are part of the OSIRIS-REx flight collection and will be curated by NASA. The flight witness plates are stored under curation pristine conditions (nitrogen gloveboxes or nitrogen desiccators) in sealed containers so they are not continuously exposed to nitrogen flow. The scientific value of flight witness plates has not been established on a time scale of decades, even for the plates stored in sealed containers. In addition, any subdivision of individual witness plates results in the loss of some of the active surface of the witness plates. Therefore, the SAT may consume more than 25 % of the flight witness plates, if requested, but allocations to the SAT cannot make more than 50 % of a specific exposure history (always open, pre-collection, pre-stow, post-collection, and post-stows) non-pristine.

The witness plate material will be included in the initial catalog and will be available for request by the scientific community. Once the remaining pristine witness plate material for any individual exposure history is ≤ 25 % pristine, the cadence of allocation of witness plate material will be re-evaluated by NASA curation based on the information learned from analyses of the OSIRIS-REx flight witness plates.

6.4 Flight Hardware

The sample canister was delivered to the OSIRIS-REx curation lab and opened in a pristine glovebox. The canister filter was removed and dissected into multiple parts during PE. Based on lessons learned from Stardust, the canister filter components are not expected to store trapped volatiles on year-plus-timeframes, so the scientific value of these components would substantially diminish over time, therefore, the entire flight filter needed to be machined open

for some of it to be allocated to the SAT in October 2024. In other cases, when possible, allocations of hardware to the mission SAT will comprise 25% or less of the hardware type.

The rest of the sample canister components delivered to the OSIRIS-REx curation lab will be initially stored in the curation environment (nitrogen gloveboxes or nitrogen desiccators) and will remain there until all asteroid material adhering to them that can be practically harvested within a glovebox has been removed. After all the asteroid sample is effectively removed from flight hardware items, curation pristinity is no longer an important factor in the scientific value of these items. For allocations to the broader community, flight hardware requests will be considered on a case-by-case basis by an allocation review board.

7. CONSERVATION PLAN DETAILS

7.1 Cadence of Allocation to the Broader Scientific Community

Curation intends to solicit proposals for allocation of OSIRIS-REx samples with fixed deadlines, the first of which will be 2 months following publication of the initial catalog (catalog publication on March 25, 2024, and proposal deadline on June 25, 2024). This will be the only solicitation in year 1 following sample return. The cadence of future solicitations is planned to be twice in year 2 and 3. After year 3, the deadlines will continue to be twice a year until a potential transition to rolling deadlines is recognized to be appropriate to support a dramatic reduction in the quantity of requests being received.

7.2 Restrictions on Allocations to the Broader Scientific Community

The quantity of samples available to be allocated to the broader community incorporates two limiting factors:

(1) The curation laboratory and staffing capacity to allocate samples from the collection between sample requests deadlines

(2) Retaining pristine sample for future investigations/generations

Regarding the capacity to allocate samples for approved requests, after the first allocation review, requests may be approved for up to 20 samples. The approved requests after the first review will be fulfilled before approved requests from the second review and so on and so forth. The capacity to allocate is based on a fixed number of samples rather than number of requests, because one request may include multiple samples, which therefore requires commensurate laboratory and staffing capacity to fulfill. Beyond the up to 20 samples per request deadline, additional requests may be evaluated as ‘selectable’ and will stay under consideration for the next sample request allocation review. The number of samples to be allocated per request deadline will be adjusted as activities that compete for curation laboratory and staffing capacity evolve.

Regarding the quantity, a maximum percentage of the initial pristine mass of the NASA bulk sample will be available to be converted to non-pristine material for allocation based on the remaining pristine sample at each application deadline (Table 2). During Phase F (sample analysis) of the OSIRIS-REx mission (September 24, 2023 to September 23, 2025 or, if extended, the point at which phase F officially ends), members of the OSIRIS-REx SAT will not be eligible for sample requests outside of the mission sample analysis allocation process. For the first and subsequent request deadlines during mission phase F, it will be calculated that 25% of the bulk sample will be made non-pristine by the sample analysis team even though some of that sample may not have been allocated yet. At the end of Phase F, the available pristine material will be calculated by the exact quantities allocated to the SAT and/or made non-pristine by processing requested by the SAT. In the early years of the collection, we anticipate most years these percentages (Table 3) will not be reached because the cap on the number of samples to be allocated will be the limiting factor.

Over time, the quantity of material in the collection that is no longer curation pristine is expected to increase as non-pristine samples are prepared for allocation and samples that are not fully consumed are returned from investigators to NASA curation. As long as it would not compromise the proposed scientific studies, as evaluated by the AARB panel or stated in the request, non-pristine material will be preferentially allocated to minimize the quantity of pristine sample that becomes non-pristine. For example, if a proposed study could be achieved with an existing and available thin section, that section would be allocated rather than making a new thin section.

As pristine material is allocated (and made non-pristine), the percentage of pristine material available for allocation will decrease over time. The percentage of the remaining pristine material that will be available for allocation will decrease in a somewhat stepwise manner as milestone percentages of pristine returned sample are reached (Table 2). For instance, once the percentage of pristine returned bulk sample drops below 50 %, no more than 5 % of the remaining pristine material may be allocated within a year. Once the percentage of pristine returned bulk sample drops below 40 %, no more than 4 % of the remaining pristine material may be allocated within a given year.

Table 2: Long-term Limitations for Allocation of Pristine Bulk Samples

Bulk Sample Still Pristine	% Existing Pristine Material Available for Allocation Per Year
< 80 %	10%
< 70 %	9%
< 60 %	8%
< 50 %	5%
< 40 %	4%
< 30 %	3%
< 20 %	2%
< 10 %	1%

Table 3: Maximum Possible Initial Mass Allocation of Pristine Bulk Samples

	Pristine Returned Bulk Sample		Maximum % of Pristine Material Open to Allocation at Next Request Deadline
	grams	% bulk	
Landing	121.6	100	
End of PE	85.4	70.2	10%
End of PE + 1 Year	76.8	63.2	9%
End of PE + 2 Years	70.7	58.1	8%

7.2 Requests for Allocations Exceeding Long-term Mass Limitations and RAC samples – Including for Consortia Studies

There may be research that is valuable to the community and/or to NASA that requires more pristine material than the default quantity per year (Table 2) (e.g., *in situ* contact pad material, entire witness plate, mass that exceeds allocation limits for a given lithology, etc.). Requests that exceed 20 % of the regular pristine allocation limits for a given year (Table 2) must provide justification beyond a regular allocation request, and the panel will evaluate whether the proposed work merits the additional sample. Requests that exceed 20 % of yearly mass limits may include consortia studies, but they are not fundamentally restricted to only consortia studies. In addition, requests for RAC samples or material that require subdivision of the 10 'largest' particles (Table 4) will also be required to provide additional justification that a smaller particle cannot be used to accomplish the proposed work, and the panel will evaluate whether the proposed work merits permanent subdivision of that particle that is special, by its size, among the collection. In addition, during preliminary examination OREX-434000-0 and

OREX-800001-0 were designated as part of the RAC for OSIRIS-REx. OREX-434000-0 is a contact pad (#12) with a particle that does not resemble the other particles observed on the contact pads. OREX-800001-0 is an aggregate sample that includes a higher proportion, qualitatively, of fine-sized sample material that remained on the TAGSAM top plate after the bulk sample pour, and thus has a distinct history compared to the rest of the bulk collection.

A subset of the bulk sample has been stored frozen and/or in hermetically sealed containers for long-term curation. Therefore, these samples are considered RAC samples, thus sample requests that require opening these containers require very compelling justification about why those specific samples are needed, and such requests will be subjected to additional levels of scrutiny prior to approval.

Sample requests that exceed the individual request allocation limits will undergo additional levels of review before they can be approved. These requests will first be reviewed by the appropriate panel of the AARB with instructions for a higher level of scrutiny. If the allocation board encourages the sample allocation, the request will be submitted for further review by the Astromaterials Curator and the Chief Scientist for Astromaterials Curation within the Science Mission Directorate, who will also apply a higher level of scrutiny compared to nominal requests.

Table 4: OSIRIS-REx Restricted Access Collection (RAC)

Sample Number	Original Weight	Notes
OREX-434000-0	n/a	Contact Pad 12
OREX-800001-0	4.133 grams	fine-grained aggregate sample that remained on top plate after bulk sample pour
Largest Particles Identified by Preliminary PSFD During Early PE		
		Size order
OREX-800014-0	6.236 grams	1
OREX-800015-0	0.418 grams	4
OREX-800016-0	1.183 grams	7
OREX-800017-0	2.042 grams	5
OREX-800018-0	2.896 grams	3
OREX-800019-0	2.251 grams	2
OREX-800020-0	0.576 grams	6
OREX-800021-0	0.592 grams	8
OREX-800022-0	0.728 grams	9
Frozen and/or Hermetically Sealed		
OREX-800036-0	1.267 grams	Hermetically sealed
OREX-800037-0	0.559 grams	Stored at - 80 °C
OREX-800038-0	0.763 grams	Hermetically sealed
OREX-800039-0	0.891 grams	Stored at - 80 °C
OREX-800040-0	1.196 grams	Stored at - 80 °C
OREX-800041-0	2.562 grams	Stored at - 80 °C
OREX-800042-0	1.021 grams	Hermetically sealed
OREX-800043-0	0.779 grams	Stored at - 80 °C

8. References

Bierhaus E. B., et al. (2018) The OSIRIS-REx spacecraft and the Touch-and-Go sample acquisition mechanism (TAGSAM). Space Science Reviews 214, 1-46.

Dworkin, J. P., et al. (2018) OSIRIS-REx Contamination Control Strategy and Implementation. Space Science Review 214, 1-19.

Lauretta, D.S., et al. (2017) OSIRIS-REx: sample return from asteroid (101955) Bennu. Space Science Reviews 212, 925-984.

Lauretta, D.S., et al. (2022) Spacecraft sample collection and subsurface excavation of asteroid (101955) Bennu. Science 377, 285-291

Appendix A: Material Restrictions within OSIRIS-REx curation lab

A.1 Forbidden Materials:

- Nylon
- Silicones
- Materials and items with high potential to shed particles, including 3D printed materials

A.2 Materials allowed in gloveboxes (all must undergo OREx cleaning procedure and triple bagging in polytetraflouroethylene (PTFE))

Glass:

- Schott Amiran Low Iron Laminated
- Pilkington OpticWhite (uncoated glovebox windows only)
- Fused Quartz/Fused Silica
- Borosilicate Glass, Borosilicate including Crown Glass (BK7)
- Soda-Lime silicate glass, lead-free (above without Boron)
- Sapphire/Sapphire Glass

Plastics (In order of preference):

- Polytetraflouroethylene (PTFE; Any metal with PTFE coating is acceptable w/approval)
- Flourinated Ethylene Propylene (FEP)
- Polyvinylidene Flouride (PVDF; For Tubing)
- Perflouroalkoxy Alkanes (PFA; For Tubing)

Metals (In order of preference):

- 6061 and 6063 Aluminum (Unfinished or Clear anodized)
- 316/316l Stainless Steel
- 304 Stainless Steel
- Biodur 108 Surgical Stainless Steel
- 2024 Aluminum (Clear anodized)
- 301 (annealed), 302, 303 Stainless Steel
- 2205 stainless steel (only for use on container sight glasses for contact pads and public display samples)

Finishing for metals:

- Clear and Hard Anodized Aluminum
- Pickled and Passivated
- Electro-polished
- Gold Plated (For electrical contacts only)
- Satin/Pebble/media blast

Elastomers:

- Viton (FKM)
- Chlorosulfonated Polyethylene (CSM, Hypalon)

A.3 Materials allowed in OSIRIS-REx Curation Lab (not in gloveboxes):

- All of the materials allowed in gloveboxes (A.2)
- Cleanroom Polyester (gowning and similar uses)
- Nitrile (gloves and similar uses)
- N95 masks (fresh/newly opened mask upon entry to lab suite)
- Polycarbonate (Lexan)
- Additional stainless-steel alloys beyond those approved for glovebox use (e.g., hand tools, carts, tables)
- Computers, cameras, and microscopes that live permanently in the curation lab (minimize contamination that would 'hitchhike' on this type of equipment coming and going from the lab)
- Encapsulated LED light sources for above