RATES: Vision and Implementation Plan
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1) Vision: Rates and Ages Transform Earth Science (*RATES*)

RATES is a new decadal initiative that seeks to understand the tempo, drivers, and feedbacks in the Earth System over the last 4.5 billion years by increasing NSF resources dedicated to geochronology. The timescales of Earth processes span more than ten orders of magnitude from less than a second to greater than ten million years. From the drivers of long-term climate and landscape change to the distribution of critical resources and prediction of geohazards, the critical variable for evaluating hypotheses is ***time***. Indeed, our understanding of the rates of Earth processes are entirely dependent on geochronology. And yet, too many studies in the Earth Sciences do not have time constraints for their processes – which, as time is the fourth dimension, is akin to not having latitude or longitude. Long-term, extensive, and dedicated funding has been directed towards understanding the 3D structure of the Earth and its change over the last ~100 years through the permanent geophysics programs at NSF and *ad hoc* decedal initiatives such as Earthscope. A commensurate dedication of funding to geochronology is required to provide temporal and spatial resolution to the other 4.5 billion years of Earth History.

No time is better than now for such an initiative. New analytical and computational methods have combined to create a watershed moment for reconstructing time in the geological record. We are now poised for major advances in understanding the Earth System both by accelerating the development of integrated techniques for measuring time, and by acquiring large sets of strategically targeted geochronology data that quantify the timing and rates of climatic, biologic, geomorphic, tectonic, geomagnetic, and magmatic processes and the links among them. However, the advances necessary for quantifying Earth history and for testing hypotheses for cause-effect relationships between different Earth processes are hindered by i) limited access to the geochronology facilities and data; ii) insufficient support for development of new techniques and multi-chronometer approaches; and iii) a paucity of dedicated pathways for educating the next generation of diverse, cyber-savvy geochronologists.

To address these challenges, we envision an initiative called *RATES* (Rates and Ages Transform Earth Science) consisting of two key components: a dedicated NSF science program and a National Geochronology Consortium. The *RATES* science program will coordinate collaborative research among scientists from a spectrum of disciplines and range of research institution types by offering funding opportunities that together will enable the most important *RATES* research through a merit-based panel-review process. The *RATES* initiative will also establish a National Geochronology Consortium (NGC) to produce and digitally house high-density temporal datasets, enable collaborative technical innovation, and provide enhanced training in the collection and interpretation of geochronological data that will support transformative science. With crucial investments in human-, technical-, and cyber-infrastructure, the 69 labs distributed across the nation that comprise the AGeS3 (Advancing Geochronology

Science, Spaces, and Systems; see section below) lab network are poised to transform into the NGC, enabling unprecedented advances in quantifying time in the Earth system.

RATES is a new opportunity to build a cross-disciplinary community under the umbrella of constraining the rates of processes and feedbacks in the Earth System throughout Earth history. The *RATES* initiative will coordinate and integrate the efforts of researchers and students across the geosciences in identifying community priorities and challenges related to using time as the unifying research tool. For example, communities across the GEO, such as the Ocean Drilling Program, Polar Program, Sedimentary Geology & Paleobiology, and Marine Geology & Geophysics, have been working for decades to create better age models in sedimentary successions, but these efforts have been largely siloed. The advances we seek will not emerge from geochronologists working in isolation or from geochronology data collected indiscriminately without context. Rather, big science progress requires synergistic studies among interdisciplinary researchers on targeted samples within well-understood geological, structural, stratigraphic, topographic, and geochemical frameworks. In short, we believe that everyone within NSF GEO will benefit from this initiative because everyone wants better time constraints in their research, whether they be geologists focused on some aspect of Earth history or modelers needing better ground-truthing.

In this white paper, we first highlight three research areas with important societal relevance that are ripe for targeting with *RATES* science. The document then explains the work within and beyond the GEO community over the past two decades that both established the scientific need for geochronology investments and contributed to the vision outlined here for both the NGC and the *RATES* initiative.

2) Transformative Science on the Foundation of Time

Time is what separates Earth Science from all other sciences: consequently, “every significant advance in geochronology has produced a paradigm-shifting breakthrough in our understanding of Earth history” (2015 It’s About Time NSF report). The development of $^{40}Ar/^{39}Ar$ dating of young basalts enabled calibration of the geomagnetic polarity timescale and contributed directly to the plate tectonic revolution; the advent of (U-Th)/He dating has allowed direct evaluation of links among plate tectonics, erosion, topographic uplift, and climate change; high-precision U-Pb dating has documented the coincidence between eruption of large igneous provinces and major biological extinction events; and the advent of ^{14}C and U-series dating has linked glacial-interglacial cycles to orbital forcing and enabled precise synchronization of globally distributed records of abrupt climate changes (2015 It’s About Time NSF Report).

Here we highlight three themes in the Earth Sciences that are not only poised for significant breakthroughs resulting from an increased focus on time calibration, but are also connected to some of the most significant problems facing modern society. Across all three, a common theme is the central role of precise timescales and rates in advancing our understanding of fundamental processes governing the Earth system.

2.1) Paleoclimate and planetary habitability. Climate change is one of the most challenging problems facing humanity today. In making the decisions needed to address it, we are fortunate to be armed with a rich archive of past climate experiments in the geological record that we can learn from. These episodes of climate change occurred at a variety of timescales, with different drivers and responses from the Earth system. However, the chronology essential for testing and understanding mechanisms of past changes and the Earth system's response to them is sorely lacking. For example, we do not know whether carbon released during Eocene hyperthermal events happened over 100, 1000 or 10,000 years, nor do we have good constraints on how quickly CO_2 levels decreased after them. Rates of carbon cycle perturbation and recovery are similarly vague for other major events in the geological record, which are commonly associated with biological extinctions. These huge uncertainties in rates make it very difficult to test or model potential mechanisms for climate change and the response of the Earth system.

For climate records and Earth system models of geological events to be relevant for our understanding of humanity's future, we need geochronology of the highest resolution possible. While achieving dates of the required precision is a challenge, it is one we can rise to given the types of analytical improvements that *RATES* could provide. We also must leverage the integration of multiple geochronometers and with relative dating tools such as cyclo- and magnetostratigraphy (themselves reliant on geochronology for correct placement in geologic time). Achieving these goals requires both substantial efforts among a community of geochronologists with the resources for technical improvements and connections between the geochronologists and other geologists who study these records.

As we have learned from our current climate challenge and anthropogenically driven extinction event, climate and environmental change are closely linked to biological evolution and habitability. Further calibration of the geological record would allow us to ask fundamental questions about habitability, including: What are the conditions on a planet required to sustain complex life? How and when did life evolve on Earth, and how did major revolutions of life on Earth relate to major changes in Earth's climate and environment?

Answering these questions requires better understanding of the Early Earth and establishing cause and consequence between atmospheric and ocean chemistry, climate, tectonics, and signatures of life–an effort that relies critically on geochronology. For example, the age of the first molecular evidence for animals overlaps with the age of the greatest episodes of climate change in the geological record, so-called Snowball Earth events, but the uncertainties in the ages of both milestones are too great to determine which came first or whether there is any causal relationship between them. Geochronology of sedimentary successions without volcanic ash beds using, for example, Re-Os geochronology of black shales, requires further development to provide the age and stratigraphic resolution to answer questions of synchroneity between atmospheric oxygen, fossils, and ocean chemistry. These types of advances require not only more dating of targeted stratigraphic records, but also support for advances in geochronologic techniques as applied to these records, including high-risk, high-reward innovation.

2.2) Critical mineral exploration and volcanic hazards. While at first glance, ore deposit research and volcanic hazards are seemingly disparate research areas, they are both fundamentally controlled by the tempo of magmatic processes in the crust. In particular, mineralization and volcanism are the product of shallow crustal magmatic and hydrothermal processes, which in turn are driven by mantle and crustal melting, magma transport, and magmatic differentiation and storage at various crustal levels. Whether or not systems result in significant ore deposition or eruptions depends critically on the rates of magma emplacement into the upper crust in addition to the volatile flux and magma composition.

As we transition to a society more heavily dependent on green energy, sourcing elements such as Li, REEs, and transition metals that are critical for technology development, economization, and energy independence, will become increasingly important. The majority of these resources are derived from magmatic/hydrothermal fluids that precipitate sulfides, sulfates, carbonates, phosphates, etc., whose timescales, and therefore processes, of formation remain poorly understood. However, recent studies have shown that these deposits can form on timescales anywhere from thousands to millions of years, and may depend on magma flux, tectonic setting, and crustal depth. Understanding the initiation and duration of ore deposition is important for pinpointing the mechanisms that may drive their formation in magmatic systems, whether it be emplacement, cooling, and interaction with host rocks and hydrothermal fluids, or longer term storage of magma reservoirs that exsolve the proper ingredients for ore deposition. Time constraints of relevant precision and on relevant materials are crucial for integration with thermodynamic and numerical models for ore formation. Cross-cutting relationships in ore systems are often complex or not available, and assumptions about timescales are often wrong. Many studies constraining ore deposit formation utilize multiple long-lived radioisotopic systems (U-Pb, Re-Os, $^{40}Ar/^{39}Ar$, Rb-Sr) that require further intercalibration (decay constant and standard development) before they can be fully integrated into age models for ore processes. These types of intercalibration studies can be facilitated through the *RATES* program and the NGC.

Similarly, predicting volcanic hazards has been hampered by a lack of understanding of the timescales of magma residence in the upper crust prior to eruption. Countless media articles discuss the presence or absence of magma chambers beneath volcanic centers such as Yellowstone and speculate about the implications for an eruption. However, in some models, magma may reside beneath an eruptive center for thousands to hundreds of thousands of years prior to eruption, while in others, eruptible magma bodies are ephemeral features that, if present in the upper crust, should indicate imminent eruption. These timescales are determined primarily in minerals amenable to radioisotopic dating (zircon, sanidine, plagioclase) using the U-Pb or U-Th systems as well as diffusion based geospeedometry (Mg/Fe-olivine, Ti-quartz, Mg-plagioclase) in erupted products, though these records often reveal conflicting results. Furthermore, evidence from the plutonic record – understanding why magmas do not erupt – is equally important, but restricted to older rocks where age precision is limited. Marrying these multiple records over different timescales using multiple chronometers requires increases in precision as well as intercalibration between different dating methods. Doing so will enable better understanding of how to interpret geophysical (is there magma present at depth?) and geodetic (is the surface inflating?) datasets that monitor volcanoes.

2.3) Landscape evolution and seismic hazards. The processes of erosion and sedimentation not only form the landscapes around us and provide us with the soils to grow food, but also play a central role in Earth's short- and long-term carbon cycle through silicate weathering and carbon burial. Recent improvements in the accuracy and interpretation of thermochronological data have provided constraints on erosion rates over 10s of million years, which can be used to evaluate links with fault motion, tectonics, climate, environmental, and landscape change. High resolution erosion rates in deeper time (>100 million years ago) and shallower time (last million years) are more difficult to acquire. In deep time, discrepancies in the kinetic models for thermochronometers in different systems are magnified, leading to inconsistencies in results and fundamental limits on erosion rate accuracy and precision. In more recent time, a gap in the erosion rates accessible by the lowest temperature thermochronometers and radiogenic cosmogenic isotopes leads to difficulty in bridging between million-year and modern erosion rates. Coordinated focus on calibrating kinetic models using emerging approaches as well as on cross-calibrating different systems (e.g., Ketcham et al., 2022, Report from the 17th International Conference on Thermochronology) is needed to quantify denudation rates with sub-mm/year accuracy through much of Earth history. Improvements in the accuracy of thermochronological data on these shortest and longest timescales, along with increased data coverage, will allow the integration of temporally calibrated landscape models with paleogeographic, chemical weathering, biogeochemical, and climate models. These advances promise a revolution in Earth Systems Science in which different subfields from the solid and fluid Earth can provide complementary data to each other at relevant timescales.

Landscape evolution and erosion are deeply influenced by regional stresses imposed by global tectonic plate motions. Stress and deformation in the upper brittle crust are accommodated along fault zones which, over geological timescales, produce the striking landscapes of mountain belts, but over human timescales, result in devastating earthquakes. While the mechanics of fault rupture are relatively well understood, the timescales over which faults become activated and the rates at which they propagate remain one of the biggest unknowns in our understanding of seismic hazards. While advances in geo- and thermochronologic methods applied to dating fault damage (e.g., U-Th/He of fault-plane hematite) are beginning to shed light into the timescales of fault activity, linking this information with other paleoseismological records remains a major challenge. A coordinated approach to understanding fault motion using multiple geo-, thermo-, and diffusion chronometry methods across a wide range of temperatures and timescales would provide the fundamental information needed to i) assess earthquake recurrence along major fault zones; ii) better understand –and quantify– their seismic hazard; and iii) link these with high-resolution models of rock exhumation and landscape evolution obtained from thermochronology to understand how deformation is accommodated through time along seismically hazardous fault zones.

3) *RATES: a new initiative to meet the challenges of 21st century Earth Science.*

To make progress in the research areas above requires a significant increase in the volume of geochronology data produced in coordination with a more diverse spectrum of Earth scientists, as well as resources dedicated to technique development and intercalibration. We propose a two-pronged approach to tackle these challenges head on: formalization and support for a National Geochronology Consortium (NGC) and a new NSF program with the working title of *RATES* (Rates and Ages Transform Earth Science). The NGC would be an accessible facility network that connects PI-driven laboratories with each other and the entire community of Earth Scientists who need geochronologic data to forward their science. The *RATES* NSF program provides a mechanism to fund transformative community science focused on improving and applying geochronology to critical problems in Earth Science. Below we outline that 1) there is demonstrated community support for this initiative, 2) the NSF-funded AGeS program provides a smaller-scale proof-of-concept for an NGC, 3) precedent illustrates the power of focused geochronology working groups targeting technique development as would be supported by this initiative, and 4) there is currently no mechanism within NSF to effectively support the scale of the proposed science that would leverage geochronology. Lastly, we (5) sketch a possible governance structure that could support the NGC and *RATES* NSF program.

3.1) Community support for improved geochronology infrastructure and access

The *RATES* initiative emerges from two decades of workshops, meetings, town halls, and associated documents that have organized the communities needed for its success. These efforts include EARTHTIME (e.g., Bowring et al., 2005; McLean et al., 2011, 2015; Condon et al., 2015), AGeS (Flowers et al., 2018; Flowers and Arrowsmith, 2022), EarthRates, the GSA Geochronology Division, the Gordon Research Conference series on Geochronology, and an NSF report on "Opportunities and Challenges for U.S. Geochronology" (2015 NSF report, It's About Time). These geochronologist-specific initiatives fit within the context of high-end reports from a broad spectrum of Earth scientists through the National Research Council and the National Academy of Science, Engineering and Medicine (e.g., NROES, 2012; Shapley and Noren, 2019; NASEM, 2020) that call out geochronology as a critical target for expansion in the immediate future. The findings and recommendations of the NROES 2012 and the NASEM 2020 reports were grown out of a broad community of geoscientists charged with identifying key scientific targets for the coming decades. Both reports identify the need for an increased amount of geochronology and improved access to geochronologic data.

Specifically, the *RATES* initiative will fulfill a core recommendation of the NASEM 2020 report for NSF's EAR to "fund a National Consortium for Geochronology". Sustained and substantial investments in human-, technical-, and cyber-infrastructure are required for collection of the necessary geochronology data across a vast range of temporal and spatial scales to support interdisciplinary studies that advance the *RATES* program goals. The 2020-2030 NASEM Earth in Time report outlines current problems: *"…significant issues exist with respect to providing the geochronologic information that is essential for current and future research in Earth science. Issues arise principally from the current funding model, in which most geochronology labs are supported mainly by awards to address specific science questions, with little or no funding awarded to support lab infrastructure, technique development, or educational/outreach activities... This has inhibited development of new instruments, techniques, and applications that will be needed to address future Earth science questions."* The findings of the *It's About Time* report (2015) corroborated these findings and also emphasized that there must be better mechanisms to provide access to geochronology to researchers from a broader spectrum of universities and research centers.

The community associated with the SZ4D initiative proposes to work with an NGC to achieve their scientific goals (Hilley et al., 2022, p. 174). That initiative recognizes the importance of geochronology in achieving their aims, but provides no mechanism to do so, relying instead on an initiative of the type we suggest here to exist in tandem.

To overcome these issues, the *RATES* initiative envisions a NGC with two distinctive elements: i) a shift to a more integrated research approach, leveraging multiple methods and fostering cross-disciplinary collaboration to understand the rates of key Earth processes, facilitated by a coordinated network of labs with greater capacity and accessibility, and ii) initiation and coordination of working groups to advance high priority technical goals via cross-lab partnerships and coordination. The *RATES* initiative not only offers a means of increasing the output of geochronology data nationwide through greater lab support, but also provides a network of labs willing and able to partner with groups throughout GEO as well as a mechanism to initiate these partnerships. Fortunately there is precedent for points (i) and (ii), such that *RATES* can build on the successful strategies adopted by the NSF-funded AGeS and EARTHTIME programs.

3.2) A successful facility network model for geochronology: Demonstrated precedence through the AGeS laboratory network and its collaborative science strategy

A network of accessible facilities comprises the fundamental structure of the *RATES* NGC. The range of samples analyzed (solid, gas, liquid), the types of data required (elemental, isotopic, luminescence), the volume of data envisioned, and the amount of existing technical infrastructure and expertise already distributed across the nation negate the concept of a centralized approach to a NGC. The network concept is supported by community discussion carried out as part of the 2015 *It's About Time* NSF report, which found that both those who generate geochronologic data and those who use it prefer a network built around existing and new PI-driven facilities at various scales rather than a single, centralized facility.

The AGeS lab network (AGeS, 2022), now consisting of ~120 PhD-level geochronologists and 69 labs housing the majority of the geochronology instrumentation in the U.S., represents exactly this distributed facility network. First envisioned a decade ago as a mechanism to increase access to geochronology data and training by providing up to $10k micro-funding opportunities for students to visit geochronology labs, AGeS welcomes labs to join at any time and has seen new labs grow the network every year. All AGeS labs have publicly available lab profiles with information about sample preparation, instrumentation, analytical costs, contact personnel, and the education and training experiences provided for visitors. The AGeS lab network is positioned to become the NGC with additional human-, technical-, and cyber- infrastructure investments.

The AGeS program also sets a precedent through its successful cross-disciplinary science and network-building strategy. The AGeS-Grad program not only has granted >100 micro-awards to support cooperative science projects that use geochronology data, but has catalyzed new collaborations, enabled piloting of unproven and even "risky" ideas, financed datasets published in journals ranging from *PNAS* and *Geology* to *EPSL* and *Nature Communications*, and in some cases has provided seed data for subsequently funded NSF projects. Funded AGeS research includes awards focused on climate and landscape change as well as magmatism, faulting, and tectonics. The 374 proposals submitted over the 7 proposal cycles of AGeS-Grad demonstrates the broader Earth science community demand for geochronology data and the success of its model of enabling interdisciplinary science and incentivizing new connections. We envision that AGeS as a funding program for graduate research would continue as part of *RATES*, and that the NGC would be leveraged to add new opportunities for PI-level interdisciplinary science.

3.3) Working groups to advance high-priority technical goals via NGC community partnerships

The *RATES* program would leverage the unified facility network of a NGC to support cross-lab collaborative working groups focused on advancing high priority technical goals. Such was the vision of the NSF-funded EARTHTIME initiative 20 years ago, whose success at advancing high-precision ID-TIMS U-Pb and $^{40}Ar/^{39}Ar$ lab intercalibration for calibrating the geologic timescale is an example of this approach. EARTHTIME brought together investigators from multiple laboratories in a substantive effort sustained over 10+ years to examine measurement protocols, develop community standards and tracer materials, and improve agreement between labs and chronometers. In 2003 at the start of EARTHTIME, U-Pb ID-TIMS labs could not agree on the ages of standards to better than 1-2%. Through the development of community tracer solutions, transparent data-reduction, freely available software (Schmitz and Schoene, 2007; McLean et al., 2011), and sharing of analytical protocols among U-Pb working groups, labs can now date the same material to ~0.02% (Schaltegger et al., 2021; Szymanowski et al., 2022). This is widely seen as a success that other geochronology communities would like to emulate.

RATES would focus on the three technical goals recommended by the 2015 NSF report "It's About Time: Opportunities & Challenges for U.S. Geochronology" that will advance the science priorities described in the previous section:

- "±0.01% age precision and accuracy from the Cenozoic to the Hadean (achieved by creating methods and mass analyzers of unprecedented sensitivity and resolution) to revolutionize our understanding of a broad array of Earth processes."
- "Continuous temporal coverage throughout the Pleistocene – from one week to one million years – of processes key to societal security (e.g., climate change, critical zone management, volcanic hazards, paleoseismology)."
- "Sub-mm/year denudation rate accuracy from thermochronometers, for timescales as short as 1000 years, to place geodetic deformation rates in context with long-term geologic trends."

Achievement of these technical goals, together with dramatically increased volumes of geochronology data on strategic samples, would facilitate dramatic progress in our understanding of Earth system science, from which all Geoscientists would benefit. Such lofty goals are attainable, provided sufficient resources and community leadership through the *RATES* initiative.

3.4) An NSF GEO *RATES* science program would meet a need outside the scope of other NSF programs.

A *RATES* science program would include multiple types of funding. It will support individual investigators and groups of researchers across the greater Earth science community in conducting transformative science that relies on the underpinning of time as a key hypothesis test. As noted in the previous section, it will also provide a mechanism for geochronology labs to push technical advances that hold promise for breakthroughs in quantifying climate, landscape, tectonic, and magmatic records via both individual lab awards and multi-lab, EARTHTIME-style working groups. Finally, it will invest in human infrastructure for generating data to enable *RATES* science and for developing in-lab expertise for cyberinfrastructure which both efficiently stores data at the lab level and contributes to accessible geochronology databases at the community level.

A new *RATES* GEO program would be beyond the scope of existing NSF GEO core disciplinary programs, with time being the one variable that cross-cuts all of their science. Although other recent NSF programs address different parts of the Earth system, none are focused on achieving the envisioned goals of the *RATES* program. P4CLIMATE (Paleo Perspectives on Present and Projected Climate) emphasizes the climate system, but does not encompass the solid Earth community and is not designed to advance or integrate geochronology tools. Geoinformatics supports cyberinfrastructure, but not analytical advances or interdisciplinary science questions. FRES (Frontier Research in Earth Sciences) emphasizes the connections among the Earth system, but does not have a central focus on leveraging new and imminent advances in measuring time in the geologic past. The 2022 NSF Instrumentation and Facilities solicitation now includes support for newly created laboratory technician positions and various tracks for community facilities, but does not have the scale of funding needed to meet the demand for geochronology in the research community as described in the *It's About Time* report. Also critical is that to fully leverage new technician positions in labs, an NGC is essential to coordinate those labs and connect them with a diverse set of researchers whose needs could be filled by the increase in technical support nationwide.

3.5) *RATES* Structure and Governance

As described above, the National Geochronology Consortium would consist of a coordinated network of laboratories that cover any and all types of radioisotopic chronometers, spanning all timescales and types of datable material. The NGC will be guided by a Steering Committee comprised of rotating members of diverse expertise that is charged with: i) defining science goals; ii) guiding the community towards the best ways to reach those goals; iii) providing mechanisms to connect data generators (labs) with data consumers (geoscientists of all kinds); iv) coordinating outreach and education programs; and v) organizing inreach geared at connecting labs for sharing and standardizing protocols and lab practices.

Subcommittees would represent the major branches of the NGC, including AGeS, Human and Facilities Resources, and Cyberinfrastructure, with subcommittee chairs sitting on the Steering Committee to facilitate interaction and communication between the NGC branches while providing a wide vision for its operations. Each branch of the NGC will focus on the development, application, and accessibility of geochronology to benefit the broader community of Earth Scientists and meet the scientific needs outlined in this document as well as the *It's About Time* NSF paper and the NASEM Earth in Time document. For example, AGeS provides access to geochronology to graduate students from all backgrounds; Human and Facilities Resources will focus on providing the personnel and instrumentation required to meet the demands of the Earth Science community and developing new tools to facilitate better age resolution in our chronometers; and the cyberinfrastructure initiative will focus on making geochronologic data accessible in accordance with FAIR principles and integrating geochronology with other data types in the Earth Sciences.

The *RATES* NSF science program would operate much as the EarthScope science program did to distribute funding towards the program's science goals in a peer-reviewed, proposal-driven model that ensures competitive, open access to funding. The newly implemented Instrumentation and Facilities pathways towards becoming a National Community Facility and for supporting lab technicians could be inserted into the *RATES* program to inject more funding and network it with the broader community. Some portion of the *RATES* budget would be dedicated permanently towards staff positions charged with facilitating the core operations of the NGC, including web managers, logistics coordinators, and/or requisite organizational staff who would work closely with the Consortium Steering Committee.

4) Summary and synthesis: No Dates No Rates.

The Earth Science community needs more geochronology data to make progress on transformative, societally pressing, Earth System science questions. Not only that, but more precise, more accurate geochronology is required on a wider range of geologic materials across all timescales and geologic settings. This demand has been documented repeatedly. Over the last two decades the geochronology community has taken the necessary steps to demonstrate that this demand can be met by more resources directed towards lab support, better infrastructure for outreach and access to labs, and dedicated funding towards the types of analytical developments that will enable Earth Scientists to address higher level questions related to climate, planetary habitability, critical mineral exploration, volcanic hazards, landscape change, and seismic hazards. We believe that the Earth Science community is ready for NSF funding at the GEO level for a *RATES* initiative. This initiative will achieve the above goals through a new science program and a NGC that consists of a network of PI-driven labs that, through cooperation, organization, and innovation, can drastically improve accessibility to geochronology data and achieve the types of technological advancements that are needed to provide a scientifically, time-resolved, context to society's most challenging Earth Science problems.

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Examples of Reports related to Geochronology Needs and Investment

The National Research Council's NROES report 2012: identifies investment in geochronology facilities as a major priority in Earth Science research

Transitions, 2012: the culmination of a series of workshops led by sedimentary geologists and paleontologists, which highlights the need for an expansion of access to high-precision geochronology to meet their science goals.

It's About Time, 2015: In response to the NROES 2012 report, NSF gathered a group of 7 geochronologists to research and report on the needs of producers and consumers of geochronologic data

NASEM Earth in Time report, 2020: the National Academy report outlining Earth science priorities for 2020-2030; recommends the established of a national geochronology consortium