The New U.S. Arctic Observing Viewer: A Tool for Strategic Assessment

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Executive Summary

Although a great deal of progress has been made with various Arctic Observing efforts, it can be difficult to assess that progress. What data collection efforts are established or under way? Where? By whom? How can we better plan, coordinate, and achieve scientific objectives? To help meet the strategic needs of U.S. SEARCH, AON, and other initiatives, a new resource has been released: the Arctic Observing Viewer (AOV; http://ArcticObservingViewer.org). This web mapping application covers the “who”, “what”, “where”, and “when” of data collection sites – cruise tracks, moorings, buoys, towers, boreholes, climate and weather stations, shoreline surveys, repeat vegetation plots, etc.: wherever Arctic Observing data are collected. Funded initially by the U.S. NSF Arctic Sciences Section, it will become comprehensive with time to become more broadly interagency for U.S. efforts. Information exchange and collaboration with international entities would be mutually beneficial. As a prototype, this application currently showcases a subset of observational activities. Hundreds of sites with repeat measurements are displayed, providing an overview as well as project-level and site-specific details. Users can visualize, navigate, select, search, draw, print, export, and more. The viewer is appropriately circumpolar, and includes both marine and terrestrial sites. Enhancements in functionality and scope are in motion for 2013, and feedback is appreciated. The AOV is founded on principles of interoperability, with an emerging metadata standard and open web service formats, such that participating agencies and organizations can use the AOV – as well as distributed web services – for their own purposes. In this way, the AOV will complement other existing and emerging cyber-resources, and will help science planners, funding agencies, PI’s, and others to: assess status, identify overlap, fill gaps, assure sampling design, refine network performance, clarify directions, access data, coordinate logistics, collaborate, and more to better meet Arctic Observing goals.

Introduction

“The AOS will be an international forum for optimizing resource allocation through coordination and exchange among researchers, funding agencies, and others involved or interested in long-term observing activities, while minimizing duplication and gaps.” [emphasis added]
– Call for Community Input and White Papers for the Arctic Observing Summit, 2013
The Arctic Observing community is at a crossroads. A great deal of progress has been made with observing systems and data-related activities: 1) planning and coordination associated with the International Polar Year (IPY), the U.S. Arctic Observing Network (AON), and the Sustaining Arctic Observing Networks (SAON) initiative, among others; 2) an increase in both the quantity and quality of observing activities and datasets; and 3) improvements in data access, management, and preservation by national and international data centers and systems. However, it can still be difficult for research scientists and Arctic science organizations to systematically and comprehensively assess progress, to assure that appropriate sampling designs are being implemented, and to know where to invest in new deployments. In other words, “How can we know where to go if we don’t know where we’ve been?” Also: “What resources already exist?” “Is there overlap?” “Where are the gaps?”

Indeed, questions from the AOS 2013 community input questionnaire (AOS, 2013) highlight the need for synthesis and assessment to better meet scientific objectives. For example: “What are major issues facing coordination of arctic observing activities and how can these be resolved?” “What are the current redundancies in Arctic observing activities?” “What are the current major gaps in Arctic observing activities and why should these be addressed?”

A fundamental obstacle is that Arctic science is fragmented. Arctic research tends to be decentralized among and within academia, international organizations, government agencies, scientific disciplines, various initiatives, etc. For this reason, it can be challenging for scientists or planners to obtain a complete or representative perspective on Arctic data holdings and observing activities. For a variety of reasons, it is unlikely that there will be a single data catalog or portal covering all related datasets and efforts. Furthermore, it can understandably take time for datasets to be released and be a part of the picture.

What is needed is a resource focusing on a new level of granularity: “data collection sites”. Such a resource would enable strategic assessment for ongoing data collection activities tied to SEARCH-AON and other initiatives. This tool would not be a data portal, because details such as sensor names, serial numbers, etc. – as well as the datasets themselves – are more appropriately maintained at the data archives. It would not be a project tracking system, which would lack the spatial resolution and details needed for data-related activities. And it should grow to become interagency and international. A resource guide and information portal – dispersing knowledge of the “who”, “what”, “where”, “when”, and “how” – needs to be available well before data are archived to improve the efficacy of Arctic Observing activities.

Because the data collection activities are broadly distributed by funding, administration, actual data collection, and data dissemination, the success of such a resource for strategic assessment would hinge on interoperability. Information about ongoing data collection activities would need to be shared in such a way that it is compatible with contributions from other entities, and could be harmonized and reprocessed. Furthermore, the information would need to be kept up to date. Fortunately, there have been successful precedents for establishing both: 1) community-based metadata standards (like has been done for project tracking, or with dataset-level metadata); as well as 2) open, interoperable web services (live data streams between database management systems; e.g., Johnson et al., 2011).
The end result would be a distributed yet comprehensive tracking of Arctic data collection activities. Agencies could make use of this distributed system for information sharing – through standards and web services – in their own web applications, or could take advantage of shared applications. This approach would help assure sampling design, fill gaps, and assess progress. It could also improve data access, facilitate logistics, assist with emergency response & resource management, and foster coordination & collaboration. It would benefit strategic assessment and Arctic science alike.

This paper presents an initial effort toward developing a tool to help with strategic assessment of Arctic Observing data collection activities. The Arctic Observing Viewer (AOV; http://ArcticObservingViewer.org) was released in December 2012 as a prototype web mapping application for data sites tied to U.S. SEARCH, AON, and related initiatives. With collaboration and coordination, the functionality and scope could be expanded internationally also. We also review a related tool, the Arctic Research Mapping Application (ARMAP; http://armap.org). We outline mechanisms for interoperability, including an emerging metadata standard for data collection sites, which draws heavily from a Project Metadata Standard released by the Alaska Data Integration Working Group (ADIwg), and requires only modest modification to accommodate a bare minimum of fields for ease. Last, we touch on scalability and mutual benefits for collaboration.

**Strategic Needs For Arctic Observing**

A broad and overlapping variety of national and international efforts have identified data management needs for Arctic Observing. This includes not just IPY, SAON, and the component of AON funded by the U.S. National Science Foundation (NSF), but other U.S. agencies contributing to AON through the Observing Change component of the Study of Environmental Arctic Change (SEARCH) program (e.g., NRC, 2006; SAON, 2010; Parsons et al., 2011; ADCN, 2012; ADI Task Force, 2012). On the global scale, similar needs have been identified through planning and coordination led by the Global Earth Observing System of Systems (GEOSS), the World Data System (WDS), the WMO Information Service (WIS), and the International Council for Science (ICSU), among others. These efforts have helped to clarify and advance objectives for: data sharing and publication; interoperability; preservation; coordination and governance (see Parsons et al., 2011). Importantly, most of these efforts are focused on the level of datasets. The scope and interconnectedness of data catalogs and data portals are increasing, with adoption of standards and through metadata harvesting and “brokering” technologies.

On the other end of the spectrum are project tracking systems for high-order information to guide science planning, logistics, etc. These vary in presentation, scope, and audience: e.g., multiagency and circumpolar (ARMAP; http://armap.org; Johnson et al., 2011; Gaylord et al., 2013); multiagency for the North Slope of Alaska (through the North Slope Science Initiative, NSSI; http://catalog.northslope.org); the U.S. Geological Survey Alaska Science Portal (http://alaska.usgs.gov/portal); the SEARCH Project Catalog (http://www.arcus.org/search/catalog/display); the Advanced Cooperative Arctic Data and Information Service (ACADIS; http://www.aoncadis.org); through the Arctic Landscape Conservation Cooperative (ALCC; http://arcticlcc.org/search/projects); the Research in Svalbard effort (http://wwwssf.npolar.no/pages/start.htm); an upcoming ESFRI initiative through the

But an intermediate level of tracking is needed to meet the strategic needs for Arctic Observing – through a metric of “data collection sites”. Such a resource could help address some of the objectives or goals expressed by the various planning and coordination initiatives:

“... improvement of observation density, co-location, and integration; improvement of coverage to close observation gaps; development of optimal observation and sampling strategies; ...”
– activities for the SEARCH Observing Change component and AON (http://www.arcus.org/search/aon)

“The Goal of SAON is to enhance Arctic-wide observing activities by facilitating partnerships and synergies among existing observing and data networks ("building blocks"), and promoting sharing and synthesis of data and information.”
– SAON Implementation Plan (SAON, 2011)

Theme 1: “Status of the current observing system (goals, objectives, capabilities, challenges and sustainability)”

Question 1: “What can be done to improve the design, implementation, coordination and sustained long-term operation of Arctic observing systems ...?”

Outcomes and Products: “Synthesis of the present status of the observing system, recommendations for improved international coordination, including synchronization of funding mechanisms, and a roadmap for the future observing system. ... The definition and operationalization of one or more AOS projects that will integrate two or more existing or new observing activities or networks to achieve common objectives. These objectives may be scientific, agency or mission oriented, stakeholder driven or some combination thereof. ...”
– Call for Community Input and White Papers for the Arctic Observing Summit, 2013

“The United States and the other Arctic nations require strong, coordinated research efforts to understand and forecast changes in the Arctic. ... Toward that end, and in furtherance of goals developed by the Arctic Research Commission, this plan focuses on those research activities that would be substantially enhanced by multi-agency collaboration.”

A common or distributed resource for tracking data collection activities for Arctic Observing would help meet these goals. Information would be more timely by avoiding the lag between efforts and dataset release; it would likely be less fragmented and more comprehensive than existing data holdings; and it could assist with gap analysis and network design.
The New Arctic Observing Viewer

Facing a need for the U.S. Arctic Observing Network (AON) and related initiatives, a web mapping application was created in 2012 to help with visualization, assessment, synthesis, and decision support. The new Arctic Observing Viewer (AOV; Manley et al., 2013; http://ArcticObservingViewer.org) covers the “who”, “what”, “where”, and “when” of data collection activities for AON and related initiatives. It allows funding agencies, science planners, PI’s, and others to:

- Assure sampling design.
- Fill gaps.
- Assess progress.
- Access data.
- Coordinate and collaborate.

Displayed are hundreds of sites with repeat measurements, providing an overview as well as details (Fig. 1). Users can visualize, navigate, select, search, draw, print, export, and more. They can also follow links to more information, or to the datasets themselves. Funded initially by the U.S. NSF Arctic Sciences Section, the application is circumpolar, and includes both

Figure 1. Screenshot of the Arctic Observing Viewer, showing data collection sites and a popup window with descriptive information for one of the sites.
marine and terrestrial sites. At present, the viewer displays sites mainly associated with the Thermal State of Permafrost project, as a pilot showcase. The AOV will become more comprehensive with time to become interagency, and to encompass cruise tracks, moorings, buoys, towers, boreholes, climate and weather stations, shoreline surveys, repeat vegetation plots, etc.: wherever Arctic Observing data were collected. And for the benefit of all, the viewer and related services could also become broadly international.

The application has an interactive, geospatial interface with an appropriately circumarctic basemap. Users can view and click on points, lines, or polygons – representing observation sites – to view popup windows with details on data collection activities:

- Project title
- Funding agency
- Award number
- Contact information
- Discipline
- Type of measurement
- Location
- Start date
- End date
- Latitude and Longitude
- Links to more information
- Whether data are archived
- Links to datasets

Users can also select or search for multiple sites of interest, view a table with these details, and export the results (Fig. 2). The AOV includes a “time slider” to visualize change in data.

Figure 2. The AOV, showing the Search Results table after selecting a rectangular area. The table includes numerous details of the data collection sites, including Funding Agency, and can be exported or printed. As a prototype, the AOV currently shows sites mainly tied to the international Thermal State of Permafrost project.
collection activities over time (Fig. 3). Other elements enable the ability to: pan, zoom, or move to full extent; choose a variety of map layers to view; draw graphics; add text; view a legend; measure distances and areas; view cursor location by latitude and longitude; save and print the map; and follow links to project reports and data catalog pages.

![Map of the Arctic Observing Viewer (AOV) with data collection sites and time slider](image)

**Figure 3.** The AOV, with the “Time Slider” running, which is an embedded animation for display of data collection activities through time, from 2005 to 2013.

Improvements are planned for 2013, and feedback is appreciated. Our highest priority is to build out the application, underlying database, and web services for interoperability. The existing Access database will be migrated to a spatially enabled relational database management system. “Pathways” for contributions of site information will be enabled with an online data entry form, via upload of files in a variety of formats, or through ingestion of web services (live data streams that follow a compatible standard). We will troubleshoot and problem solve this roadmap for stability by working closely with a few initial partners. This will also lead toward inclusion in the AOV database of many more sites. We will release core fields from the database as a web service using one or more open standards, for use by others in their applications. And on the radar are some improvements to the application itself: regional views (Alaska, Canada, Greenland, Northern Europe, Russia); refinements to the user interface; new tools (potentially Share Link, Go To XY, Advanced Search, etc.); and new map layers (e.g., “supersites”, imagery basemap, perhaps weather stations, web cams, etc.).
The AOV was built on – and relies on – a systems architecture of hardware and software. The prototype viewer itself was developed for use in common internet browsers by using the ArcGIS Viewer for Flex framework (v3.0). The preferred Integrated Development Environment (IDE) for coding was Adobe Flash Builder 4. Some of the functionality in AOV has been ported as “widgets” available through the framework and from a community forum, while other tools and elements required custom programming. ArcGIS Desktop and ArcGIS Server 10.0 were used to create and host the Geographic Information Systems (GIS) layers containing both spatial and non-spatial data of the application. The hosting environment includes Dell Blade servers and iSCSI storage housed within the Research and Academic Data Center (RADC) at the University of Texas El Paso (UTEP) on the high speed Lonestar Education And Research Network (LEARN). Bulk purchasing agreements for university hardware and enterprise software licenses are leveraged at no cost to this project while ensuring support for open web service standards endorsed by the OGC.

The database underlying the prototype AOV is based on modification of the Project Metadata Standard established by the Alaska Data Integration work group (ADIwg; ADIwg, 2011; http://www.aooos.org/adiwg). A subset of fields and tables within the ADIwg template for Microsoft Access was selected for simplicity. To handle information specific to data collection sites, three new fields were added to the Geometry Object tables (geometry_object_category, location_accuracy, and timestamp). The database was initially populated with sites for a collaborative U.S. AON project, the Thermal State of the Permafrost. High-order information on other AON projects was harvested from the Arctic Research Mapping Application (ARMAP; http://armap.org). Other AON-related site information was collected manually as available from the Advanced Cooperative Arctic Data and Information Service (ACADIS; http://www.aoncadis.org) and other sources. Routine queries of the Microsoft Access database are exported to an ArcGIS SDE feature class, which is then published as an editable ArcGIS Geoservices REST Feature Service for display, query, and editing within the viewer.

An upgrade in systems architecture planned for early or mid 2013 includes new Dell PowerEdge R620s servers virtualized via VMware vCenter Server 5.1.0, with ArcGIS Desktop and ArcGIS Server 10.1, and an enterprise geodatabase (Microsoft SQL Server 2008 SP2 or PostgreSQL 9.1.3, coupled with ArcSDE v 10.1 SP1). These components are able to work with common standards and to deliver open services.

The Arctic Research Mapping Application

A companion application serves a somewhat different purpose, scope, and audience. The Arctic Research Mapping Application (ARMAP; Johnson et al., 2011, Gaylord et al., 2013; http://armap.org) is a suite of online, interactive maps and data services in support of U.S. Arctic science. ARMAP allows users to:

- Learn more about research projects in any region of interest or scientific discipline
- Explore available data or possible collaborations
- Plan and coordinate field logistics
- Use the online mapping tools to meet your own project’s specific goals

Users can navigate to areas of interest and explore information about field-based scientific research in the Arctic (Fig. 4). Research sites are shown as points with links to details about
Distinct from AOV, ARMAP focuses on projects, not data collection sites. Also, ARMAP includes AON-related projects, but goes beyond this to thousands of other Arctic research projects. The flagship application, ARMAP 2D, is broadly interagency, and now includes projects from eighteen U.S. agencies and organizations (NSF, BLM, BOEM, NOAA, NPS, USGS, and more; many are a part of the U.S. Interagency Arctic Research Policy Committee, IARPC). Also available is ARMAP in Google Earth, as well as a range of web services for cross-platform data sharing and use by other entities in web or desktop applications (Field Research Projects, Site Place Names, Arctic Base Map, etc.; available in a variety of web service formats such as: ArcGIS Geoservices REST Feature Service, KML, OGC-compliant WMS & WFS, REST, and TXT).

![Figure 4. The Arctic Research Mapping Application (ARMAP), with thousands of Arctic research projects funded by – or carried out by – eighteen agencies and organizations.](image-url)
To be comprehensive and interoperable, ARMAP makes use of the project tracking standard established by the Alaska Data Integration Working Group (ADIwg; http://www.aooos.org/adiwg). The web service for Field Research Projects we host at http://armap.org/rest.aspx conforms to this standard, and is consumed by a variety of organizations (Fig. 5). More to the point, some of the projects in the ARMAP 2D mapping application are accessed dynamically – on the fly – from agencies that have released their own web service endpoints conforming to this standard. It is in this way – through coordination and collaboration on compatible standards and web services – that progress can be made for strategic assessment.

Figure 5. An example of an implementation of the ADIwg Project Metadata standard, shown above as XML code captured from the ARMAP REST endpoint that is publicly available at http://www.polar.ch2m.com/nsf/armap.svc/projects?format=xml&schema=full&v=1.0.8.0. This web service provides information on over 2500 projects (field based and modeling) which are funded primarily by US entities in the circumarctic region.

Interoperability

Interoperability for information sharing fundamentally relies on the creation and adoption of community-based metadata standards and web service formats. Various ongoing planning and coordination efforts for Arctic data management have identified interoperability – generally speaking, and usually in the context of dataset-level metadata – as a priority (see, for example: SAON, 2010; Parsons et al., 2011; ADCN, 2012; ADI Task Force, 2012). There is a broad range of standards, protocols, and “best practices” that are well established in the geospatial community, as well as in other aspects of cyberinfrastructure and data management (e.g., Sorenson et al., 2001; Di and Ramapriyan, 2010; Johnson et al., 2011; see also the Open

To advance strategic assessment of Arctic Observing activities tied to U.S. SEARCH-AON and possibly other initiatives, we advocate for modification of the Project Metadata Standard established by the Alaska Data Integration Working Group (ADIwg; http://www.aoos.org/adiwg). This U.S.-based standard was designed for compiling high-order project information, is described in a briefing paper (ADIwg, 2011) and supporting documents, and draws primarily from the FGDC CSDGM metadata standard (as well as KML for the spatial domain). Core fields are defined in an XML schema, along with a corresponding physical data model and template. ADIwg has also been investigating ISO 19110 and 19115, and it is likely that the FGDC tags currently utilized will be mapped to ISO tags and classes in a future revision.

The AOV team has found that the ADIwg Project Metadata Standard can be refined to accommodate the increased spatial and temporal granularity of data collection sites while requiring a bare minimum of fields for ease. This approach is not intended to duplicate metadata standards for datasets or sensors. The AOV team will work with ADIwg and a few initial partners to troubleshoot and advance an enhanced exchange of information using a modified ADIwg Project Metadata Standard. The AOV team will also explore the possibility of coordinating this effort with SAON Task 2 (Polar Metadata Profile and Recommended Vocabularies), as well as SAON Task 8 (Coordination of Existing Arctic Relevant Metadata Databases and Project Directories).

As far as delivery of the information, we propose that a variety of web services be made available by participating organizations. A variety of geospatial web service standards exist, such as: KML network feeds; OGC Web Feature Service (WFS) and Web Map Service (WMS) formats; an open GeoServices REST Specification, which is under review for adoption by OGC; the OGC/ISO Simple Features Access specification; and others. RESTful web services and SOAP protocols are also used extensively by other groups for geospatial or non-geospatial content. In the end, there are pros and cons to each web service format (performance; compatibility with database management systems, web applications, and GIS software; capabilities and functionality for display and customization, etc.). Perhaps most effective would be a modification of the REST web service format established by ADIwg for project-level information. But it usually does not create much more effort to release ("publish") web services in a variety of formats to promote broader use. Most important is that the services be open and compatible.

For interoperability of data collection sites tied to the Arctic Observing Viewer, we envision interconnected sources, processing, and hosting (Fig. 6). Sites already in the AOV database will be augmented by manually harvesting information from data centers (“data wrangling”), and – more effectively – through contributions from partner organizations via: 1) an online entry form; 2) static upload of files compatible with the new metadata standard; and, preferably 3) ingestion of compatible web services hosted by the partner agencies, directly into the web mapping application. Site information contributed in the first two ways will be quality checked. We hope to collaborate with agencies and data centers, without creating extra work for PI’s. Open web services generated from ArcGIS Server, or directly from the site database, could be used by
partner organizations and others in their own databases, web applications, or desktop applications for their own purposes. And anyone could take advantage of the display and functionality in the Arctic Observing Viewer itself.

Figure 6. Components planned for information flow related to Arctic observing data collection sites, the Arctic Observing Viewer, and interoperable web services.

There is a resource already in existence that is comparable in terms of an intermediate level of granularity. The Alaska Ocean Observing System (AOOS; http://www.aoos.org) has released a suite of web mapping applications, including two that are relevant to Arctic Observing: the Arctic Monitoring Efforts application, and a Real Time Sensors application. Both are part of the AOOS Data Portal. The AOOS tools are mainly marine, primarily target sensors, and largely encompass the Alaska region, whereas the AOV covers both marine and terrestrial realms, includes sensors as well as other types of sites where data were collected, and is circumarctic. There is some overlap (as is optimal in a distributed system, through exchange of information). But for the reasons above we consider the AOOS tools and AOV as different but complementary.

And there is also the Barrow Area Information Database (BAID; http://baid.utep.edu), with web mapping applications for data collection sites and other information and map layers, with a special focus on the research hubs of Barrow, Atqasuk and Ivotuk on the North Slope of Alaska. This resource is also complementary.

**Collaborate For Mutual Benefit**

Arctic Observing – spread as it is among various national and international initiatives – could benefit from an improved cyberinfrastructure that facilitates further integration, discovery, and analysis between funding bodies, PI’s, data centers, users, etc. One piece of that vision is to have an observing activity for the observing program – beyond individual projects, datasets, and individual agency or initiative efforts – to enable strategic assessment. Without this, it will be difficult for any of the stakeholders to optimize networks or to achieve the stated scientific
objectives. Key characteristics are: to go beyond the capacities of static inventories or even interconnected data portals; and to visualize and analyze status and progress in a time series. It is possible to build such a distributed system from the foundation already established by targeting key strategic improvements in focal areas. This will require both bottom up input and top down input. And such a resource (or interconnected set of multiple resources in an “ecosystem”) should be adaptable to changing science needs, observing platforms, innovations in data and information systems, and technology.

The Arctic Observing Viewer team will be asking soon for initial key partners to test and vet pathways for interoperability. Through collaboration we can troubleshoot the process for information exchange. Because the anticipated metadata standards and web service formats are a natural extension of solutions achieved by the Alaska Data Integration Working Group (ADIwg), the near-term collaboration is perhaps best handled among agencies that are currently part of ADIwg (with ties to the goals of U.S. multiagency AON, SEARCH, and/or IARPC). In the coming year there will be an announcement with broadcast solicitation for contributions. Regardless of timing, the development of this resource should be agile, top down endorsement is desirable, and feedback is appreciated at info@ArcticObservingViewer.org.

Specifically with regard to the Arctic Observing Summit and especially SAON, the AOV team is open to collaboration and coordination to meet common goals and needs. In other words, how information sharing for “data collection sites” could be enhanced to function internationally also. Beyond the viewer, most important is to ensure compatibility of metadata standards and related web services. In this regard, AOV could benefit from ties to other initiatives. For example, the goals and specifics described here could be coordinated with those embodied by SAON Task 2 (Polar Metadata Profile and Recommended Vocabularies), as well as SAON Task 8 (Coordination of Existing Arctic Relevant Meta-Databases and Project Directories). Also, efforts with related connections are described in other AOS white papers and statements (e.g., Pulsifer et al., 2013; McCammon, 2013; Moore et al., 2013; and Eicken et al., 2013; among others), as well as each of the four themes of the AOS. It is hoped that through planning and coordination facilitated at AOS that advances in interoperability can be made for the benefit of all parties involved.

For the strategic assessment of Arctic Observing efforts, an intermediate level resource is needed. This should not be a data portal, because details such as sensor names, serial numbers, etc.—and the datasets themselves—are more appropriately maintained at the data archives. And it should not be a project tracking system, which would lack the “spatial granularity” needed for tracking specific data collection activities. Rather, this resource should focus on “data collection sites”, with a bare minimum of metadata fields for ease, comprehensiveness, timeliness, and interoperability. Agencies and organizations tied to Arctic Observing can take advantage of the new application, and can use the collaborative and distributed web services as a tool for their own purposes, to help assure sampling design, fill gaps, assess progress, etc.
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