NOAA's S-57 to S-101 ENC Production Transition Plan

Marine Chart Division, Office of Coast Survey

Version	Description of Change	Effective Date	Review Date
1.0	Initial document	11/21/23	05/21/24

Introduction

The goal of the S-101 Transition is to enhance NOAA's S-57-based electronic navigational chart (NOAA ENC®) production system to enable concurrent production of both S-57 and S-101 ENCs until the S-57 ENC product is retired.

Starting in 2026, new S-100-capable ECDIS systems will be available for navigational use. In approximately 10 years, the S-101 product specification will fully replace S-57. To allow ECDIS manufacturers and mariners time to transition their platforms, the International Hydrographic Organization (IHO) and International Maritime Organization (IMO) are supporting a "dual fuel" period when use of both S-57 and S-101 ENCs will be allowed. As such, NOAA's Office of Coast Survey will need to support both product types for the foreseeable future, starting in 2026 when S-100 ECDIS systems are accepted for operational use.

Dual S-57/S-101 coverage will be built out geographically, leveraging NOAA's recent ENC gridding effort and migrating NOAA's underlying chart database to a new S-101-capable schema. While the S-101 specification allows for additional offerings in encoding objects, the goal of this initial effort is to build S-101 ENCs that are as safe as the existing S-57 coverage. After the transition, those additional capabilities of the S-101 specification can be built out.

Referenced Documents and Key Terms

Three International Hydrographic Organization (IHO) documents are referenced in this plan:

S-57 IHO Transfer Standard for Digital Hydrographic Data – This is also known informally as the "S-57 ENC product specification." It defines the format and content for all current electronic navigational chart (ENC) production.

S-100 Universal Hydrographic Data Model – The S-100 standard provides a framework under which many new products complying with the model (such as S-101) may be specified. The IHO's Implementation Strategy can be found here: https://iho.int/en/s-100-implementation-strategy

S-101 ENC Product Specification – This defines the new S-100-based ENC product, which will ultimately replace the S-57 ENC.

Dual Fuel - The ability to produce or ingest both S-57 ENC and S-101 ENC data. This document describes the transition to a dual fuel production capability. An S-100 compliant ECDIS is said to be dual fueled.

ENC Cell - A single ENC chart product, consisting of the base "triple zero" file of a new edition, such as US5PSMBE.000, and any associated update files with incrementally increased extension numbers, such as .001, .002, etc.

NIS (Nautical Information System) - A database and schema created to support both S-57 ENC and traditional paper/raster chart production, which is used in the current production system. This document uses the retronym "S-57 NIS" to refer to this legacy production database. The term, "product neutral NIS" refers to a database that would support outputting both S-57 ENCs and S-101 ENCs.

Business case

Transitioning NOAA's ENC production pipeline to one capable of supporting both S-57 and S-101 products is an investment in the future of navigational products, prioritized in NOAA Office of Coast Survey's Strategic Plan and underpinning NOAA's Precision Marine Navigation program. The IHO sets these standards to ensure alignment across hydrographic offices' products. Looking forward, S-101 provides the base map for other S-100-based products, such as S-102 (bathymetric surface), S-104 (water levels), and S-111 (surface currents); these additional products will not work with S-57 data. As such, it is the enabling data specification for the S-100 ECDIS systems coming online in 2026, and eventually replacing all existing ECDIS.

The transition to S-101 production also improves the standardization across US chart data holdings. The tools used to automate the migration from S-57 to S-101 will require greater consistency of data encoding than currently exists for some features. While resolving these inconsistencies will initially be an extra burden, the effort will result in higher quality, more useful ENC products in both S-57 and S-101 formats.

For mariners, the S-100 ECDIS will be a single bridge tool that integrates numerous streams of data supporting safe navigation. The S-101 specification provides a much-needed update to the ENC product, improving on 30 years of lessons learned with S-57. S-101 allows for ENCs to more easily be modified as the need for new features or attributes arises. Improvements in data modeling and encoding will provide navigators with the ability to better customize and declutter their ECDIS displays.

Operational S-101 and S-100 ECDIS Implementation Schedules

The operational version of S-101, version 2.0.0, is scheduled for approval in 2024 and will offer a more stable product specification with fewer new issues and changes in its requirements. IHO's S-101 implementation timeline requires the availability of S-101 ENCs starting in 2026, followed by a period of "dual-fuel" production to allow for an ECDIS and a Hydrograph Office transition period. The IMO's ECDIS performance standards have been updated such that after January 1, 2026, S-100 ECDIS will be optionally available for use. After January 1, 2029, S-100 ECDIS will be mandatory for new ships. Until all ships are operating with S-100-capable ECDIS, hydrographic offices will need to publish both S-57 and S-101 ENCs. It is unclear how long this dual-fuel production period might last, but it is estimated to be around a decade.

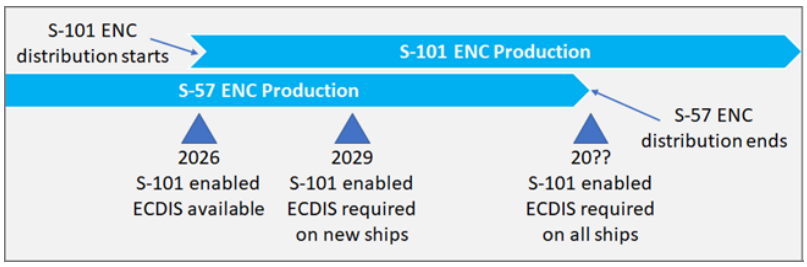

Figure 1. ECDIS functionality milestones for ships subject to IMO regulations, and timelines for the start of S-101 ENC distribution and end of S-57 ENC distribution.

Dual-Production System Options

Several options to achieve a dual ENC production capability have been considered. All of them require the use of ENC data conversion software tools—either continually during production or just once for an initial database conversion. There is not a one-to-one mapping between S-57 and S-101 features, as each ENC product specification models many features and attributes differently. It would be impractical, costly, and overly time consuming to develop an entirely automated data converter, so some level of human editing or other intervention will have to be accounted for in considering the use of conversion tools in any of the dual ENC production options.

Yet any option that uses conversion tools as a routine part of production would be especially burdensome and inefficient, requiring cartographers to resolve post conversion issues for ten or more years during the dual-fuel ECDIS period. It is also unclear how update files would be created between new ENC editions using conversion tools. Revisions exported directly from a database (with no need for any conversions) would be straightforward using existing, well understood methods.

Option 1 – Single S-57 Database: Continue to output S-57 ENCs from the current production database, then use an S-57 to S-101 converter to create an S-101 ENC for each S-57 cell output.

This is a simple solution to implement as it does not require any changes to the production database schema and S-57 to S-101 converter tools have already been developed. However, this approach would also require the greatest degree of human processing after conversion to resolve translations that are difficult to automate. Furthermore, reliance on a S-57-based production system makes no progress towards S-57's eventual retirement.

Nevertheless, this might be an ad hoc approach to produce a small number of S-101 ENCs for testing or demonstration purposes. This might also be a cost-effective option for hydrographic offices that only maintain a small number of ENC cells.

Option 2 – Single S-101 Database: Convert S-57 ENC production database to an S-101 production database, output S-101 ENCs, then use an S-101 to S-57 converter to create an S-57 ENC for each S-101 cell output.

This would initially take more resources and take longer to implement, because a new S-101 database schema would have to be created and few S-101 to S-57 converters have been developed. IHO guidance on S-101 to S-57 conversion is forthcoming in 2024. However, tools to convert ENCs from S-101 to S-57 might require less human post processing than converting ENCs in the other direction as option 1 does. Thus, this might be more cost effective than option 1 in the long term.

Option 3 – Two Databases: Retain an S-57 ENC production database and also create a second, S-101 ENC production database by converting S-57 ENC data to populate the new S-101 schema. Then use each database to maintain and output each of their respective ENC types.

This option is the least efficient and riskiest of the four discussed here. It introduces an independent production line, reminiscent of the raster and paper chart production line that

NOAA is in the process of shutting down. New source data would have to be compiled separately into each database, doubling the work and invariably introducing small differences as cartographers make different compilation decisions.

Option 4 – Single Product Neutral Database: Convert S-57 ENC production database to a neutral product (or dual product) database, then output both S-57 and S-101 ENCs directly from the single database. While supporting both products, the database schema would be more similar to S-101, because (a) the mapping from S-101 to S-57 is simpler than from S-57 to S-101 and (b) the additional capabilities of S-101 beyond S-57 will eventually need to be populated.

Like option 2, this requires creating a new database schema to replace the S-57 database, but it would be more complicated because the database would need to support maintenance of two different ENC formats. This schema has yet to be developed or tested. However, after the initial conversion of the database, finished ENCs of each type, and their updates, could be output directly with no need for further data conversions and associated post-processing. Thus, while being more complex to implement, this option potentially provides the most efficient production solution: one in which cartographers can focus on data compilation and encoding, and not on post-processing to resolve ENC data conversion issues.

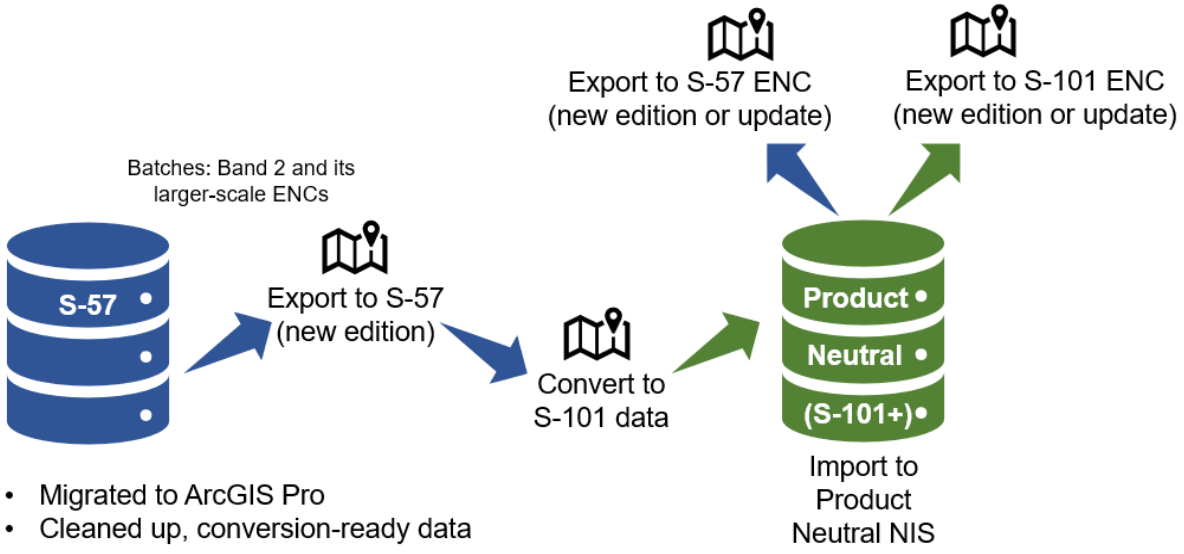

Figure 2. Basic Components of ENC Production System using one Dual-Product Database (option 4).

Table 1: Comparison of dual-production approaches.

	Pros	Cons
Option 1 – Single S-57 Database: Continue to output S-57 ENCs from the current production database, then use an S-57 to S-101 converter to create an S-101 ENC for each S-57 cell output.	● Simple implementation: does not require changes to the production database schema ● S-57 to S-101 converter tools already developed	● Requires greatest degree of human processing after conversion to resolve translations that are difficult to automate ● Reliance on S-57-based production system makes no progress towards S-57's eventual retirement ● Several S-57 to S-101 converter tools available, but all yield different results ● An S-57 update file will not convert to an S-101 update file
Option 2 – Single S-101 Database: Convert S-57 ENC production database to an S-101 production database, output S-101 ENCs, then use an S-101 to S-57 converter to create an S-57 ENC for each S-101 cell output.	● More cost effective in the long term ● Tools to convert ENCs from S-101 to S-57 likely require less post-processing than converting ENCs in the other direction ● No disruption when S-57 is retired	● Initially takes more resources and time to implement, because a new S-101 database schema would have to be created ● Fewer S-101 to S-57 converters have been developed/tested. ESRI does not currently offer one. ● An S-101 update file will not convert to an S-57 update file
Option 3 – Two Databases: Retain an S-57 ENC production database and also build a second, S-101 ENC production database by converting S-57 ENC data to populate the new S-101 schema. Then use each database to maintain and output their respective ENC types.	● Relatively simple initial implementation ● No disruption when S-57 is retired	● Doubles work: new source data compiled separately into each database ● Introduces another independent production line to maintain ● Would introduce small differences between products as cartographers make different compilation decisions
Option 4 – Single Product-Neutral Database: Convert S-57 ENC production database to a neutral product database, then output both S-57 and S-101 ENCs directly from the single database.	● Most efficient long-term production solution ● Finished ENCs of each type, and their updates, could be output directly with no need for further data conversions and associated post-processing ● No disruption when S-57 is retired ● Co-produced S-57 and S-101 update files are possible	● More resources and time to implement. A new neutral database schema would have to be created. Such a schema has not yet been developed/tested.

Recommended Implementation

NOAA endeavors to migrate its S-57 NIS database to a product-neutral database capable of exporting both S-57 and S-101 ENCs, built out to support the maintenance of an initial suite of dual S-57/S-101 ENCs in 2026. Such a database is necessary to produce the set of base ENCs, both S-57 and S-101, as well as both sets of additive/subtractive update files. This is the preferred approach for other large Hydrographic Offices that manage their ENCs in a database format, including those that use Esri production software (e.g., Denmark).

The S-57 data encodings need to be evaluated and adjusted to ensure that the NIS migrates efficiently using automated converter tools without substantial manual cartographic interventions. The policies documenting those encoding changes in NOAA's Nautical Chart Manual are the first step in this effort, as these changes need to be done uniformly and in an organized manner. Given uncertainty in the S-101 product specification, it would be most prudent to prioritize features/attributes that are unlikely to change (e.g., CTRPNT), allowing additional time for more discussions and decisions at the IHO working group level on the more controversial features/attributes (e.g., Group 1 objects).

The initial migration from the S-57-based NIS to a product-neutral NIS will have to be done in stages. The new database can be built out geographically, following gridded ENC coverage. Doing so where there is also S-102 and S-111 coverage would allow for broader interoperability testing. NOAA intends to migrate discrete batches of ENCs to keep track of chart maintenance items during the transition and avoid conflicts with neighboring S-57 datasets. The planned scale for each batch is a gridded band 2 ENC and all of its larger-scale-band ENCs (Figure 3).

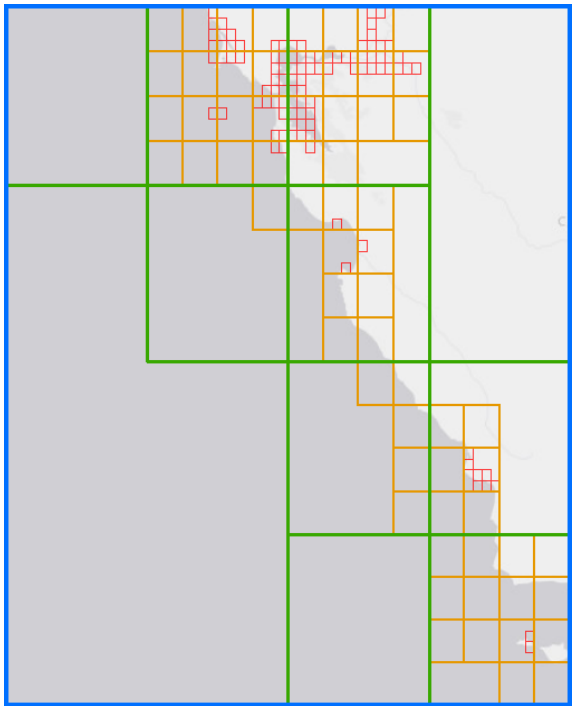

Figure 3. Reschemed band 2 ENC cell (blue) covering California Coast from San Francisco to the Channel Islands. Each ENC can hold as many as 16 cells of the next smaller scale - band 3 (green), band 4 (orange), and band 5 (red). Collections of nested ENCs, such as this, can provide a modular way to transition to a new database.

Each batch may need to be exported as new edition S-57 ENCs to capture any pending changes (Figure 2). Then the ENCs would be converted to S-101, with any non-automated encoding changes done after conversion. Those S-101 ENCs would be loaded into the new product-neutral NIS. As it stands, Esri has an ArcGIS Pro-based tool capable of converting from S-57 to S-101 on an ENC-by-ENC basis, with a configuration file that allows for some customization of the conversion logic. However, it is worth noting that there are mismatches in the outputs between Esri's converter and those provided by other software providers, highlighting that continued development and testing is required with these tools.

Currently this is only a cell-by-cell solution, i.e., export a new edition S-57 ENC, convert it to an S-101 ENC, and import that ENC data into the new NIS. One possible alternative might be the direct translation of the S-57 NIS to a product neutral NIS using Feature Manipulation Engine (FME). In either case, upon conversion, some manual cleanup will still be required. There may be room to automate some of this process, recognizing that substantial human review will be required to make sure features have been appropriately translated.

Once an ENC is moved into the new NIS, it will only be maintained there. Forthcoming guidance from the IHO's ENC Working Group on backwards conversion from S-101 to S-57 should help enable exporting an S-57 product from an S-101 or S-101-like database. IHO's determination that some S-57 features and attributes are no longer relevant in S-101 ENCs demonstrates that some features may no longer need to be maintained in S-57, making this translation to both formats simpler.

Data Cleanup Requirements

Over half of the S-57 features have some change in the S-101 specification. Some of these changes can be handled by data conversion tools without any data cleanup, whereas other changes will require re-encoding or other measures prior to conversion.

Drop features and attributes

Some are deprecated S-57 features or attribute values that are no longer relevant and are not captured in the S-101 data model. When a legacy S-57 feature or attribute is not necessary for safe navigation, a converter tool would drop the unsupported feature or apply a NULL value to the attribute. For example, many S-57 control point (CTRPNT) categories are not supported in S-101. While triangulation marks and boundary marks translate to the S-101 Landmarks feature, benchmarks, fixed points, main and secondary horizontal control stations, and observation spots are all unsupported in S-101.

In the case of S-57 attributes not supported in S-101, so long as the attributes are not mandatory in S-57 or used to drive portrayal, the attributes will not be retained in a dual-fuel environment, as they were intentionally removed from the new ENC standard. Taking this approach simplifies the database schema required to support dual fuel production.

Re-encode S-57 features or attributes

Other features and attributes that are unsupported in S-101 but are required for safe navigation must be reencoded to fit into the S-101 data model. For example, S-57 recommended tracks

(RECTRC) of type area are not a supported feature geometry in S-101. Therefore, these areas need to be reencoded in S-57 as recommended tracks of type line or as another supported traffic routing area feature (e.g., fairway, two-way route part, deep-water route part).

Standardize S-57 encoding

Other attributes require standardization or editing to support automated conversion to the S-101 data model. S-57 to S-101 conversion tools leverage textual information attributes (e.g., INFORM) to translate features and that text must be uniform for the tools to work efficiently. Consider, for example, fog signals whose sound signals are radio- or call-activated. In S-101 this is captured with newly available values for the attribute signal generation (SIGGEN in S-57), but is currently encoded as text in the S-57 attribute INFORM—variably as "MRASS", "(MRASS)", "Sound signal can be activated by keying VHF-FM Ch. 81A 5 times within 10 seconds," etc. If an automated tool were to read INFORM to populate the new signal generation values, the INFORM attribute would need to have standard text, or at least a standard substring, across features.

On the other hand, NOAA-specific encoding practices might provide opportunities to enrich S-101 data. One example is OBJNAM for aids to navigation. In S-101 OBJNAM is remodeled into a complex attribute, allowing the option for multiple names and a Boolean toggle for their display. Because of the standardized structure in these object names, it is possible to automatically encode abbreviated display names in S-101 with a post-conversion script. Such a capability would allow users to substantially reduce ECDIS screen clutter, e.g., buoy "10" vs. "Tanapag Harbor Channel Buoy 10."

Global population of attributes

Some mandatory S-101 attributes would need to be populated globally, either through the conversion process or afterward. One example is the sounding accuracy attribute (SOUACC) for features underwater/awash rock (UWTROC), wrecks (WRECKS), and obstruction (OBSTRN), in waters less than or equal to 30 m. In S-101 these SOUACC values are converted to the S-101 attribute Spatial Quality, which is mandatory for those features in shallow water (≤ 30 m). Few of NOAA's shoal soundings currently have SOUACC encoded. Therefore, a global change or a customizable parameter of a conversion tool, would be useful for tackling these issues. In many cases these attributes can be initially filled with a null or unknown value to meet ENC validation requirements.

Table 1 summarizes IC-ENC's list of potential S-57 to S-101 feature/attribute conversion issues and the corresponding recommended action, based on the IHO conversion guidance. While some issues are clear and actionable, the majority are potential conflicts requiring review of existing data and any necessary adjustments to ensure standardization. It is not yet known how many individual instances of each issue type exist in the S-57 production database.

Table 2: Summary of S-57 to S-101 conversion issues identified through the development of IC-ENC Conversion Readiness Checks, based on S-65 Annex B 1.1.0, S-101 1.1.0 and S-101 DCEG 1.1.0.

Number of issues	Pre-Conversion	Post-Conversion	Potential Action
27			No action required (acceptable data loss in S-101)
12	X		Amend S-57
106	X		Review and amend S-57, if required
3	X	X	Review and amend S-57/S-101, if required
45		X	Review and amend S-101, if required
2		X	Amend S-101

The remodeling of geometries

S-101 introduces new features meant to provide more specificity than some of S-57's broadly defined features. Some new features are accompanied by a change in geometry type, which, because of the complexity in topology, requires manual cartographic editing to translate across product specifications. To produce both geometry types from a product-neutral database would require double-encoding the feature in both geometries (maintaining it in two places).

As an example, in S-57 the United States would encode a COLREGS boundary as a "very narrow area" CTNARE (caution area). In S-101, there is a new feature Collision Regulations Limit with line (curve) geometry. If the COLREGS CTNARE area is changed to a Collision Regulations Limit line in a product-neutral database to support S-101 production, how can a topologically compliant CTNARE be recreated for an S-57 product without storing and maintaining that data in two places? Unless a sufficiently nuanced database schema can be developed to handle this complexity, new S-101 object types with new geometries will not be usable until after the dual-fuel period. For the initial push toward dual S-57/S-101 production, having both ENC products as similar as possible eases the transition at the cost of deferring some of S-101's benefits. Still, CTNARE is another example where standardization is an investment worth making. Eventually legacy S-57 production will no longer be required and standardized data will help realize S-101's full capabilities.

Finally, the S-101 specification introduces changes to Group 1, Skin of the Earth features (Depth Area, Dredged Area, Land Area, and Unsurveyed Area). While in S-57 FLODOC, PONTON, and HULKES are all Group 1 feature types, in S-101 they are not Group 1 feature types. On conversion from S-57 to S-101, this can be addressed by adding an Unsurveyed Area underneath the corresponding Floating Dock, Pontoon, or Hulk. However, for the reverse process, where the Unsurveyed Area and Floating Dock, Pontoon, or Hulk cannot overlap in the S-57 product, the

unsurveyed area would have to be omitted. In a dual-production database, both would need to be stored, but a sufficiently configured exporter could select which features should be included in the S-57 and S-101 ENC, based on geometric rules (i.e., if unsurveyed area intersects another S-57 group 1 feature).

Policy and Process Implications for NOAA's Marine Chart Division

To make ENC data conversion-ready ahead of 2026, and ensure consistent application and documentation of any required changes, the Nautical Chart Manual Volume III will need to be updated with the alternate encodings discussed above. The IHO standard S-65 Annex B, "S-57 ENC to S-101 Conversion Guidance" is the guiding document for these changes. IC-ENC has also done substantial research while developing their S-101 Conversion Readiness Checks, which are available as a supplementary resource.

Given the time required for the Cartographic Order (CO) process used to review and publish changes to the Nautical Chart Manual, and the likelihood of a large number of changes being needed, the development of COs to support S-101 conversion should start as soon as practical.

Changes could be introduced all at once, or phased in as the policy decisions are made. Whereas rolling out all changes at once might be easier to communicate across the Division, a phased-in approach allows for more incremental change as data is touched. In either case, the new encoding guidance will need to be followed to make progress towards S-101 production. Many of these changes may be most efficiently addressed in a targeted manner (e.g., with one or a few cartographers making the change across the NIS to ensure consistency and build momentum, or as a global change in the NIS), but that would need to be carefully done and deconflicted to make sure the changes are only required once. A system for documenting and tracking bulk NIS changes would also need to be developed.

As of March 2023, IC-ENC has suspended its S-101 Conversion Readiness Checks when it validates NOAA ENCs submitted for distribution. These are custom checks built by IC-ENC meant to assist member states with preparing their data for conversion to S-101, but NOAA's reduced validation service level no longer provides these checks. As the checks are not actionable until MCD policies are in place to reflect any changes, their absence at this stage reduces the administrative burden on IC-ENC validators. As 2026 approaches, these checks should be reinstated to ensure data is ready for S-101. Another possibility is their incorporation into ArcGIS Maritime's tools to help Hydrographic Offices prepare their databases for S-101.

While not an issue for the initial transition from S-57 to S-101, as S-101 ENC data is augmented in the future, any changes in data collection requirements will need to be communicated to source providers, such as NOAA's Remote Sensing Division or the Hydrographic Services Division.

S-101 Transition and Related Marine Chart Division Activities

NOAA Custom Chart Application Development

While not an immediate benefit, NOAA's transition to S-101 will add value to its NOAA Custom Chart tool (NCC). As ENCs are translated to S-101, the NCC tool will continue to rely

on S-57 ENCs until all S-101 coverage is available. The application will then be modified to ingest only S-101 ENCs, taking advantage of S-101's improved cartographic attributes. Esri's software, upon which NCC is built, does not currently provide this capability. The NCC output is expected to be similar, regardless of the type of ENC input. The long dual-fuel production period will provide more than enough time to transition NCC to ingest S-101 ENCs before S-57 ENC production ends.

Migration to ArcGIS Pro

NOAA's Marine Chart Division (MCD) currently uses Esri's ArcMap software to produce ENCs. However, Esri announced that future updates to its current maritime tools, as well as implementation of its new S-101 production tools, will only be supported in ArcGIS Pro. Thus, MCD plans to migrate its S-57 ENC production to ArcGIS Pro in 2024. This is a high-risk, near-term step in the critical path to S-101 production (Annex B), requiring continued engagement with Esri at all levels.

The software platform change will have associated uncertainties and a learning curve that will, at least initially, slow down productivity. Shortly after use of ArcGIS Pro starts, co-production of S-57 and S-101 ENCs will begin, likely reducing productivity further.

S-101 Transition and Dual Production Time

In the near-term, the migration to a dual-fuel pipeline has the risk of taking a substantial amount of time. Even if the process were nearly fully automated, the time required to export all US cells, put them in a new database, and then export two new editions (one S-57 and one S-101) will not be trivial.

While designed to bridge a gap, the dual-fuel period may continue for a long time (>10 years), saddling NOAA with producing multiple, navigationally equivalent products. As such, NOAA requires a long-term, stable solution for producing both S-57 and S-101 ENCs, or seamlessly converting across those formats with little clean-up on either side.

Rescheming NOAA ENC Suite

The initial build-out of S-101 coverage will be done geographically, likely following gridded band 2 ENCs and all the larger scale ENCs they contain. The top 30 US ports will be the initial priority. Following the gridded cells allows for bounded, discrete sections of data to be migrated to an S-101-based format where it will subsequently be maintained. As such, the move to S-101 will start in gridded areas. Gridding is currently focused on building out coverage of usage band 4 and 5 ENCs. After completing coverage at those scales, efforts will move to band 3 ENCs and then band 2 ENCs. Dual ENC production is planned to start at the beginning of 2026, but completion of the gridding phase of ENC rescheming is not expected before the end of 2026. Thus, although converting ENC data to S-101 will be organized around reschemed band 2 footprints, the actual gridding of all band 2 and 3 ENCs may not yet be completed when the data conversion begins.

NOAA's gridding efforts have substantially reduced the number of ENC scales. Yet, these scales are out of sync with what is required by S-101, in which ENC display scales are aligned with

standard radar navigation ranges. Adjusting the compilation scales of ENC features and metadata should happen as data is systematically touched. A change in the scales requires a new edition ENC, and the gridding effort is accelerating, so building this step into the subsequent application of National Bathymetric Source data would be a prudent way to address this. In areas where the National Bathymetric Source data has already been applied, such as in New England, the scale adjustment will still need to be done.

Application of Critical Corrections and Routine Maintenance as S-57 Data is Converted

While a batch of S-57 ENCs is worked on to migrate to S-101, normal chart maintenance will need to be deferred for those ENCs. Critical chart updates will have to be maintained on the S-57 side and continued to be published. After a chart is then in the new database, those critical updates will have to be reapplied before publishing the new S-57 and S-101 editions. Geographic areas with sparser critical updates, e.g., Alaska, would be able to more quickly address these.

Staffing and Training Considerations

Substantial time is required to update charting policies, prepare S-57 data for conversion and to test accuracy and efficiency of the conversion. This work will happen amidst the two related division-wide, transformational activities discussed earlier: Rescheming the US ENC product suite and migrating production tools and processes from Esri's ArcMap to ArcGIS Pro.

Gridding is currently consuming nearly half of MCD's chart-production resources, much of the remainder being engaged in the maintenance of existing charts. MCD cartographers will have migrated to and be familiar with the new ArcGIS Pro production software when S-101 production begins in earnest. However, there may still be unexpected challenges and the tail end of a learning curve to overcome while cartographers adapt to using the new software.

Precisely predicting the level of effort required for each of these three activities is difficult, especially as unexpected difficulties arise, processes are refined, and cartographers gain experience and greater efficiency over time. MCD management should routinely review progress and interdependencies amongst the efforts, and rebalance resources allocated to each to ensure that appropriate outcomes are achieved.

A model for completing this work might consist of a trial conversion from S-57 to S-101 in a test region, followed by each MCD production branch managing the build out of their own S-101 coverage. The trial could consist of converting one gridded band 2 ENC and all the larger scale ENCs nested within its footprint, by a team staffed by members from each production branch. Those team members would then return to their branches to begin converting the remaining ENCs to S-101 in groups nested within one band 2 cell at a time. Management at the Branch level would follow the ENC gridding efforts and would allow for prioritization of areas based on local expertise and the parallel buildout of coverage across regions. Beyond the experience of the ENC rescheming, MCD also went through a similar cross-cutting data migration with the initial loading of its S-57 NIS. The need to grid and rescheme existing ENCs, maintain that data with critical updates, and complete the preparations needed to transition to a dual S-57/S-101

production system highlight the importance of developing and using highly efficient, automated tools/converters.

The National Geospatial-Intelligence Agency (NGA) will be migrating its production system to enable production of both S-57 and S-101 ENCs at the same time MCD is. As NGA uses the same production tools, they may also serve as a resource for testing and evaluating technical solutions, and will be able to benefit from NOAA's migration experience as well.

Annex A - Estimated dual-production implementation schedule

Tasks	FY23		FY24				FY25				FY26			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Data/Software														
Standardize/amend encodings required for conversion process														
Test conversion of S-57 cells: QC encoding changes, test software														
ArcGIS Pro implementation testing														
ArcGIS Pro in Production Branches														
Populate new data required by S-101 in test area(s), as applicable									?	?				
Dual-fuel S-101 production in test area(s) - test team									?	?				
S-101 operational production begins														
Policy/Procedure														
Update Nautical Chart Manual for conversion-ready S-57 ENCs														
Update Nautical Chart Manual with S-101 requirements														
Vendor Engagement														
Database design for S-101														
Test conversion/migration process efficiency														
Transition to co-production of S-57 and S-101 ENCs (migration of databases)														

S-100 ECDIS phased in

Annex B – Risk Matrix

Probability and Impact of risk occurring: (High, Med, Low)
Outcome: Possible results if risk occurs.
Mitigation: Possible actions to forestall risk or reduce impact of risk.

Risk	Prob	Impact	Outcome	Mitigation
Esri is slow in delivering an S-101-capable database.	High	High	Less time available to migrate NIS and begin dual fuel production before 2026	Engage with Denmark, NGA, and Esri to refine requirements, support testing, and provide feedback. Esri is slated to release their design in March 2024.
Delay in ArcGIS Pro dual fuel production tools	High	High	Dual-fuel S-57/S-101 production cannot begin	NOAA is engaged with Esri developers for the migration from ArcMap to ArcGIS Pro, so that work will continue through the transition to dual-fuel production.
ENC gridding is not completed by the end of 2026	High	Med	Some smaller scale band cells (which are planned to be gridded last) will not be ready for conversion to S-101. Limits where S-101 coverage can be built out	Prioritize building S-101 in gridded areas. Ungridded cells could be converted to S-101, but this would ultimately require gridding of both S-57 and S-101 cells.
S-101-related Cartographic Orders not implemented in S-57 NIS prior to 2026	High	Med	Conversion to new NIS is inefficient and requires additional manual changes to encodings	Develop global change process Dedicate a very small team to implement the changes as they are published
Time required to migrate S-57 NIS to product neutral NIS is excessive.	Med	High	Dual-fuel capability will be delayed or reliance on other, less efficient dual-fuel production methods may be required.	Prioritize testing and development of S-57 converter to ensure clean conversion with fewer required post-conversion fixes
Nautical Chart Manual 2.0 not available in 2026 with S-101 encoding guidance (including those mandatory changes that can only be made after conversion)	Med	High	Policies not in place for S-101 production and maintenance	Build out NCM 2.0 content in tandem with COs
S-101 specification continues to change significantly during the transition (before 2026).	Med	Med	Some schemas, policies, procedures, manuals, guidance and training may have to be re-modified and tested.	Continued engagement in IHO's ENC Working Group and S-101 Project Teams

			ENC production and MCD workforce will take longer to ramp up to full efficiency.	Put forth requested changes to S-101 as soon as possible. By end of 2024, S-101 2.0.0 (operational version) will be in place
S-101 specification continues to change significantly after the transition (after 2026).	Med	Med	Additional time required to review impacts and implement changes to products or transition process	Put forth requested changes to S-101 prior to implementation.
Additional time or resources required to maintain and output both ENC products is excessive.	Med	Med	Fewer resources available for other MCD priorities	Support development of S-101 to S-57 converters, as those may eventually become advanced enough to support S-57 needs on the distribution end.
The Chart Standards Group is not able to keep up with the demand for new Cartographic Orders (COs) to make S-101 ENC production related changes to the Nautical Chart Manual.	Med	Med	Conversion to new NIS is inefficient and requires additional manual changes to encodings	While first S-101-related COs focus on low-impact features/attributes with few instances, subsequent COs will focus on higher-impact S-57/S-101 mismatches
Training all MCD cartographers in the use of ArcGIS Pro and the new dual-fuel production process takes longer than expected.	Med	Med	Delayed progress building S-101 coverage	ArcGIS Pro will be first used for ENC maintenance and then gridding. Classroom training for some staff is scheduled for late FY23 or early FY24
The S-101 database delivered by Esri is not capable of S-57 ENC production	Low	High	Dual-fuel capability will be delayed or reliance on other, less efficient dual-fuel production methods may be required.	Engage with Denmark, NGA, and Esri to refine requirements, support testing, and provide feedback
IHO ENC Working Group is slow in providing guidance for S-101 to S-57 conversion.	Low	Med	Delays in S-101 to S-57 converter availability	Support ENC Working Group's development of the guidance document
MCD does not identify and make all the ENC-production-related changes needed in non-Nautical Chart Manual documents, such as Standard Operating Procedures.	Low	Low	Introduction of new features/attributes that are not allowable in S-101	Update affected documents as Cartographic Orders are published