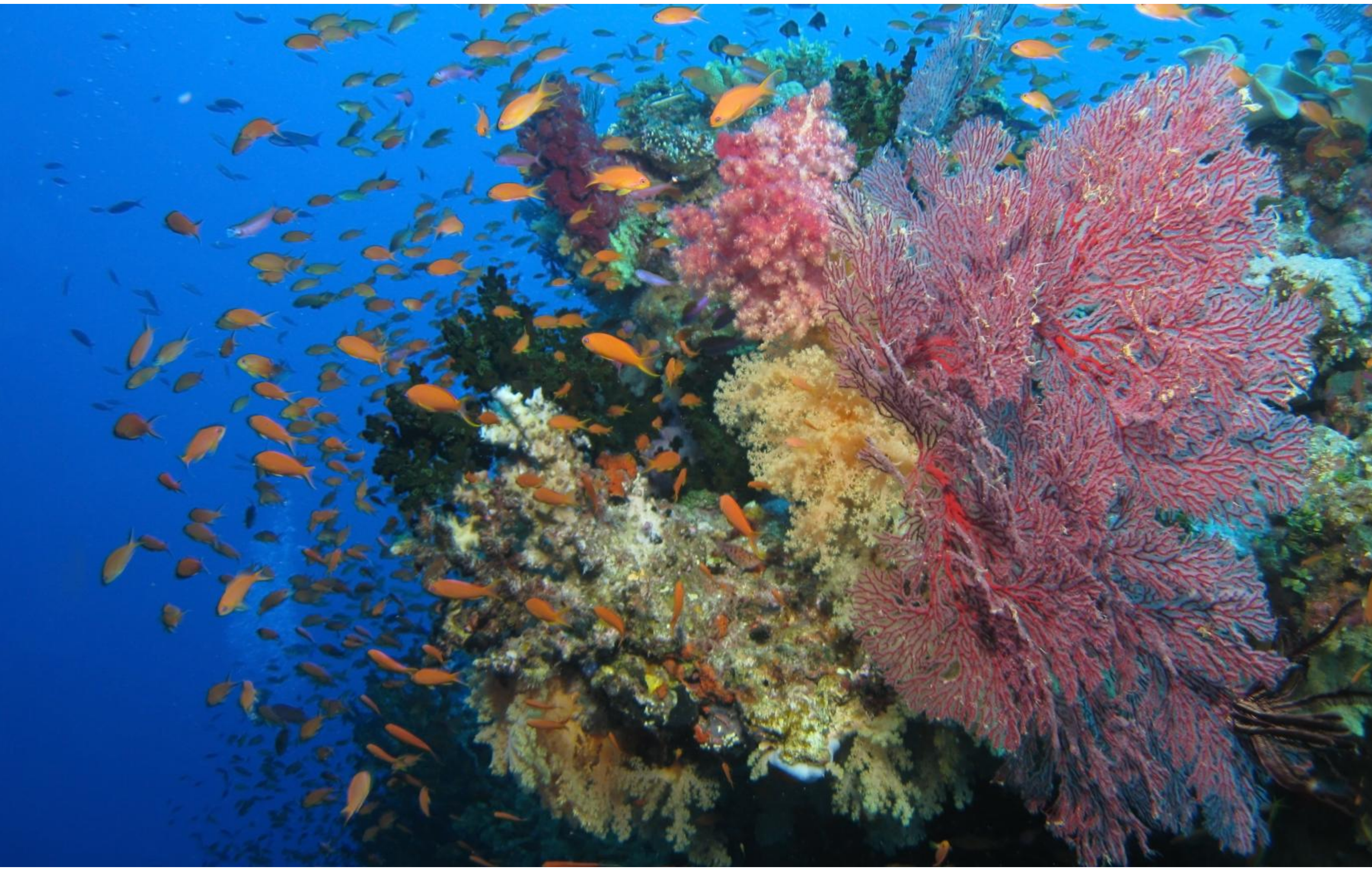
COTS Control Innovation Program

TECHNICAL REPORT

Information infrastructure to underpin and accelerate innovation in crown-of-thorns starfish (COTS) control

Cameron Fletcher, Mojtaba Rezvani



Australian Government | REEF TRUST

Great Barrier Reef Foundation

Australian Institute of Marine Science

CSIRO

James Cook University Australia

The University of Queensland Australia

Information infrastructure to underpin and accelerate innovation in crown-of-thorns starfish (COTS) control

Cameron S Fletcher[1], Mojtaba Rezvani[2]

1. CSIRO Environment, Townsville, QLD
2. CSIRO Environment, Canberra, ACT

COTS Control Innovation Program | A research and development partnership to better predict, detect and respond to crown-of-thorns starfish outbreaks

Inquiries should be addressed to:

Cameron Fletcher
CSIRO
cameron.fletcher@csiro.au

This report should be cited as

Fletcher CS, Rezvani M (2026) *Information infrastructure to underpin and accelerate innovation in crown-of-thorns starfish (COTS) control*. A report to the Australian Government by the COTS Control Innovation Program (54 pp).

Funding Acknowledgement

The COTS Control Innovation Program aims to accelerate the development of innovative surveillance and control methods to manage outbreaks of coral-eating starfish on the Great Barrier Reef. The Program is a collaboration between the Great Barrier Reef Foundation, Australian Institute of Marine Science, Commonwealth Scientific and Industrial Research Organisation, James Cook University and The University of Queensland. The Program is funded by the partnership between the Australian Government's Reef Trust and the Great Barrier Reef Foundation.

Traditional Owner Acknowledgement

The COTS Control Innovation Program extends its deepest respect and recognition to all Traditional Owners of the Great Barrier Reef and its Catchments, as First Nations Peoples holding the hopes, dreams, traditions and cultures of the Reef.

Disclaimer

Copyright

Contents

List of Figures

Acronyms and Abbreviations

AIMS	Australian Institute of Marine Science
API	Application Programming Interface
AWS	Amazon Web Services
CCIP	Crown-of-thorns starfish Control Innovation Program
COTS	Crown-of-thorns starfish
COTS IS	Crown-of-thorns starfish Information System
CSIRO	Commonwealth Scientific and Industrial Research Organisation
eDNA	Environmental DNA
EOTR	Eye on the Reef Database
FAIR	Findable, Accessible, Interoperable, Reusable
FMP	Field Management Program
GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
LTMP	Long-Term Monitoring Program
RDS	Relational Database Service
RJFMP	Reef Joint Field Management Program
RIMReP DMS	Reef Integrated Monitoring and Reporting Program Data Management System
RRAP M&DS IS	Reef Restoration and Adaptation Program Modelling & Decision Support Information System
SALAD	Scooter Assisted Large Area Diver based

EXECUTIVE SUMMARY

Almost every innovation in crown-of-thorns starfish (COTS) control requires information from multiple places to be collated, analysed, and interpreted. Real world impact is achieved when the outcomes of these innovations are delivered timely and accurately to decision makers. Reducing the overheads of accessing and sharing information not only facilitates innovation within individual components of the COTS Control Innovation Program (CCIP), but it also allows innovations in one area to support innovation efforts in other parts of the Program, accelerating and amplifying impact. The purpose of this CCIP project (CCIP-R-01 Information Infrastructure) was to design and develop an information system that would facilitate greater sharing of, and access to, COTS data.

To better understand and address these information challenges, a data needs analysis of current COTS data, processing and decision-making workflows was conducted. This analysis identified three key types of data in use: 1) Field Program or Input Data; 2) Modelled and Processed or Intermediate Data; and 3) Output or Decision Data. The review of data needs revealed that for many users, the primary need was Intermediate Data, such as COTS density estimates, rather than Input Data, such as raw COTS cull data. The COTS Information System was designed to further enhance the way intermediate data is captured by enabling the recording of dataset provenance details.

This technical report outlines the design and initial implementation of the COTS Information System, developed in response to these needs, to provide the foundations for efficient, secure, and reliable sharing of information amongst managers and researchers. The architecture of the system focused on the fundamental components required to enable efficient and reliable data sharing amongst a cohort of researcher and manager users, including a metadata catalogue to document and make searchable what data is available, a federated data registry and repository to provide access to the data, and a provenance store, process register and repository, to track the way data is processed to create new data.

The system was implemented in prototype form using the Microsoft Power Platform, which is a subset of the Microsoft Office 365 productivity tools familiar to many managers and researchers. The Microsoft stack was selected to support potential future integration with the existing tools that are used by managers and researchers such as Microsoft Power BI, as well as providing compliance components such as cross-organisation authentication with single sign-on and access control.

The COTS Information System is designed to be accessed via Microsoft Teams or the Power Apps dashboard. It is intended to enable users to register datasets and processes they have developed to inform COTS research so they can be more readily found and reused. Users will have access to a number of search methods to find data or process information, and can either access open records directly or request access for protected records. Backend automations are designed to support the quality of metadata entered into the system, and to link data and process metadata to create provenance records.

The COTS Information System is intended to provide enabling technology for major innovations from a number of projects across CCIP by sharing of data between different projects across the Program, while another related project (CCIP-R-02 Empirical Decision

Support) intends to utilise Control Program data to make real-world decisions. Together with innovations introduced in project CCIP-R-02, the COTS Information System aims to establish a foundation for the digital transformation of COTS research and management into the future. CCIP-R-01 and CCIP-R-02 together provide the basis for two major innovations: 1) improved pathways for automated preparation of COTS Control Program data, and 2) future digital delivery of research insights via the COTS Information System, Manager Dashboards and the On-Water Decision Support System.

Two key attributes extend the COTS Information System beyond a traditional data management system: 1) the ability to register Processes, and 2) the ability to track Provenance. Processes are empirical methods, computer code, or computational models used to process Input data to create Intermediate and Output data. Registering Processes in the COTS Information System allows researchers to understand and reuse data generated by Processes. Even more importantly, it allows researchers to find, understand and reuse the processing code and knowledge itself to leverage innovations in one part of the Innovation Program to drive new innovations elsewhere. It allows the construction of processing pipelines, like the Reusable Digital Workflows of CCIP-R-02, where Input and Processed data could feed into other processing steps in future automated workflows to generate Output Data that can be used to inform decisions.

In these contexts, where many processing steps may be combined within a single data pipeline, the ability to track Provenance becomes vital. The COTS Information System includes a provenance tracking system that allows users to see what Input Data and Processes were combined to create an Output dataset. While this functionality is already implemented, it paves the way for future enhancements such as autonomous artificially intelligent hypothesis generation or uncertainty analysis.

The COTS Information System is intended to be a crucial step to towards streamlining access to data and multiplying innovation opportunities across COTS management and research efforts. Looking ahead, key next steps include operationalising the system to support routine data sharing with detailed metadata and decision-making workflows across the COTS Control Program, supporting COTS researchers to upload their data into the system, and exploring integration pathways with broader reef initiatives such as the Reef Restoration and Adaptation Program (RRAP) and Reef Integrated Monitoring and Reporting Program (RIMReP). These integrations would help ensure interoperability, extend the reach and utility of the system, and strengthen the foundations for a digitally connected reef research and management ecosystem in the future.

1. INTRODUCTION

The Great Barrier Reef (GBR) faces cumulative threats from bleaching (Hoegh-Guldberg 1999; Claar et al. 2018; Hughes et al. 2018, Mellin et al. 2019, Bozec et al. 2022), coral damage due to increased cyclone severity (Gardner et al. 2003; Pratchett et al. 2014), and crown-of-thorns starfish (COTS) (De'ath et al. 2012; Pratchett et al. 2014). Of these threats, only COTS can be managed today to protect coral immediately (Fletcher et al. 2020; Westcott et al. 2020; Matthews et al. 2024). To enable the urgent protection of coral on the GBR, Australia has developed a COTS Control Program that aims to cull COTS and preserve coral (GBRPMA 2017; Fletcher et al. 2020; GBRMPA 2020). COTS control is implemented via manual culling, an effective but resource intensive process. With the resources available, this allows COTS densities to be reduced to a point where coral growth can outpace COTS damage at a few hundred of the 3,800 reefs on the GBR in the absence of other disturbances (Matthews et al. 2024). Because the COTS Control Program is resource-constrained, any innovation increasing effectiveness or efficiency would allow more reefs to be protected. To address this opportunity, the COTS Control Innovation Program (CCIP) was established in 2020 to allow researchers and COTS Control Program managers from the Great Barrier Reef Marine Park Authority (GBRMPA) to work together to develop innovations that could increase the efficiency and effectiveness of COTS control.

In practice, almost every innovation in COTS control requires information from multiple places to be collated before being scientifically analysed and interpreted. The innovations underpinned by this information generate real world impact when they are delivered quickly and accurately to decision makers. This is true for a wide variety of potential innovations, from refinements to current COTS Control Program techniques, to the design and implementation of new approaches to monitoring and surveillance, or fundamental improvements to our understanding of COTS biology through a combination of fieldwork and modelling. Reducing the overheads of accessing and sharing information not only facilitates innovation, but also allows innovation in one area of COTS control research to support other innovation efforts, accelerating and amplifying the overall impact of the CCIP.

Each year, the Control Program collects large volumes of diverse data, including cull data from diver operations, surveillance data from manta tow surveys, coral cover assessments, and emerging monitoring methods such as environmental DNA (eDNA) and computer vision. Currently, these data are managed using separate tools and databases (such as the Eye On The Reef (EOTR) database) and are often extracted and shared manually via spreadsheets or reports, which can be time-consuming and error prone. Managers rely on these data to inform tactical and strategic decisions, supported by tools like Power BI dashboards and on-water data collection apps. However, the fragmented and manual nature of current data flows makes it difficult to provide timely, integrated insights across projects and teams. The COTS Information System was conceived to provide the foundation for a unified, trusted, and easily accessible platform that supports both research innovation and real-time management decision-making.

The current COTS Control Program is supported by a strong collaboration between managers, on-water operators, and researchers. The CCIP leverages COTS Control Program data to provide ecologically-informed decision making at the time and place where management decisions need to be made (Fletcher et al. 2020). It relies on a series of separate analysis, processing and interpretation workflows, each informing one or more decision-making processes (Fletcher et al. 2020). As part of CCIP, innovations in COTS control are supported by a range of research encompassing field work to better understand COTS biology and ecology, the development of new cutting-edge monitoring methods leveraging eDNA and computer vision, the refinement of empirical decision support methods, reef-scale and GBR-scale models including the integration of new ecological parameters, research into novel management options to complement manual control, and better understanding of community and Traditional Owner perceptions of COTS control (Fletcher et al. 2021).

This research project both collects data and is enabled by data from the COTS Control Program itself. Researchers regularly use data from the COTS Control Program or reuse data collected by other research projects but currently have to recreate processing steps each time data is provided. This duplication of effort is inefficient and risks the introduction of errors, as well as reducing transparency about how data is being processed to inform decision making. More importantly, it slows down innovation and reduces the potential for lessons learned in one part of the system to drive innovation elsewhere.

One key enabler of innovation within CCIP is better access to high-quality, decision-relevant data via an Information System that is accessible to managers and researchers. Project CCIP-R-01 (this project) was tasked with designing and implementing a lightweight, short-to-medium term Information System to address such needs. This project leverages modern data management capabilities to better facilitate informed decision-making in the COTS Control Program, by making data, and the ecological science used to analyse and interpret data for managers, more Findable, Accessible, Interoperable, and Reusable (FAIR) (Wilkinson et al. 2016). The Information System provides access to the datasets in a unified manner to avoid data access barriers and increase data availability and reliability. Ensuring that data in the system is matched with appropriate metadata increases its reusability across multiple models and decision-making processes. Ensuring that the data and metadata can be ingested into automated digital workflows facilitates connection of data and algorithms to decision making processes, underpinning future digital innovations. Ensuring processing code is reusable speeds up the availability of processed data and improves transparency and innovation multiplication. Together, these components provide a data sharing capability for maximum data re-use, interoperability and security.

The COTS Information System, developed and partially implemented through CCIP-R-01, provides the foundational infrastructure for data sharing, process registration, and provenance tracking across CCIP. It supports other CCIP projects by ensuring data is accessible, trusted, and interoperable. For example, CCIP-R-02 (Fletcher et al. 2026) builds on this foundation to deliver decision-ready outputs to managers via tools like the On-Water Decision Support System and PowerBI Manager Dashboards. These tools rely on the data and processes registered in the Information System to guide real-time field operations. Together, these projects demonstrate a coordinated approach to digital transformation in COTS control.

The COTS Information System (COTS IS) features six core components: 1) a metadata catalogue, 2) data registry, 3) data repository, 4) process register, 5) process repository, and 6) provenance store. In this report we detail how the COTS Information System was designed based on an analysis of manager, research and CCIP needs, the philosophies underpinning the design, the architecture of the COTS IS, user engagement, the details of how the system was implemented, and future needs and implications for management. In the

Methods (Section 2), we detail the underlying data needs and the decision-making flows and timelines required for COTS management and research that were identified during user workshops. We then outline the design philosophy employed to address these user needs. In the Results (Section 3), we describe how the system was implemented using Microsoft Office 365 productivity components, tools familiar to many managers and researchers. Section 4 (Discussion and Outputs) provides details about the way users interact with the system around four common user workflows, including data entry, data search, process entry and search, and understanding provenance, as well as detailing lessons learned from system implementation. In Research Synergies and Next Steps (Section 5) , the report outlines how the system could interact or integrate with Information Systems being developed for larger GBR initiatives, notably the Reef Restoration and Adaptation Program Modelling & Decision Support Information System (RRAP M&DS IS) and the Reef Integrated Monitoring and Reporting Program Data Management System (RIMReP DMS).

1.1 CCIP Program Logic and impact pathway

The COTS Information System is intended to drive real-world impact by ensuring that the results of fieldwork, modelling, and decision support tools are directly accessible and usable by decision-makers in the COTS Control Program. By enabling transparent access to intermediate datasets, such as COTS density estimates and recommended order of cull dive site activity, and linking them to their underlying input data and processing steps, the system will help bridge the gap between research outputs and operational decisions. This streamlining of data flow will support faster and more informed planning, coordination, and response activities. By coordinating development to align with larger efforts occurring in RRAP and RIMReP, it will avoid duplication and will enable future collaboration, interaction, and integration across research programs.

Figure 1 illustrates this path to impact, and where project CCIP-R-01 fits within the CCIP Program Logic. What is not captured in the diagram are the cross-connections to other CCIP projects such as CCIP-R-02 (Fletcher et al. 2026) that builds on the COTS Information System by using its data and provenance features to deliver decision-ready outputs to managers. It is intended to enable real-time tools like the On-Water Decision Support System and Manager Dashboards to guide field operations using the latest decision-making innovations. Many of the outputs captured in the topmost pale-yellow Activities boxes from each project will be stored in the COTS Information System (once fully operationalised) and delivered to decision support tools including Manager Dashboards and the On-Water tool via the COTS Information System. This provides efficient pathways for insights from other modelling studies, from new monitoring and surveillance systems, and from field studies to propagate into improved analyses and decision recommendations. It also provides a pathway for these recommendations to be delivered to decision makers.

This information infrastructure will not only allow data to be shared more efficiently, but more openly, reliably and transparently. Once researchers are onboarded with the Information System in the future, they will be able to quickly find what data is available, how it was collected or created, and how to access it. Standardised metadata will allow additional information, such as collection method and intrinsic uncertainty, to be captured, improving the confidence with which data can be reused. By reducing access overheads and improving the quality of shared data and research outcomes across CCIP, projects become able to leverage progress in other parts of the Innovation Program to significantly tighten, accelerate and amplify the innovation feedback loop.

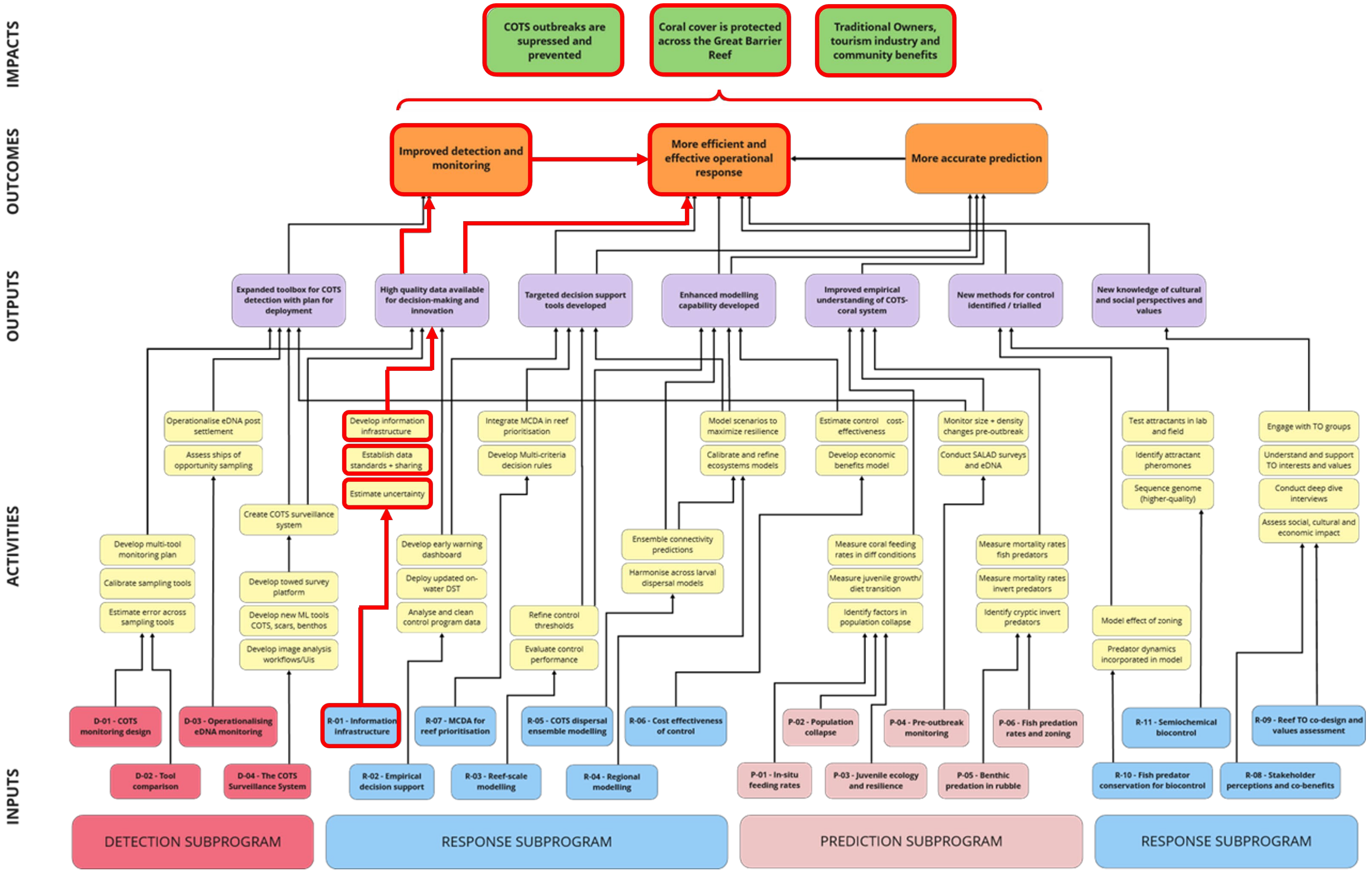


Figure 1. CCIP Program Logic. Project CCIP-R-01 and the path through Activities, Outputs, Outcomes, and Impacts are highlighted in red. Not shown are the cross-project connections, which are especially important in the case of project CCIP-R-01 due to its core role connecting research outputs across CCIP to other researchers and managers.

1.2 Project Aims

The specific aims of project CCIP-R-01 were:

- **To establish clear data-sharing arrangements and technical infrastructure to support them** across the COTS control innovation system. This enables efficient, secure and repeatable data exchange between on-water operators, researchers and managers. Furthermore, it fosters a culture of proactive data sharing, underpinned by pragmatic processes that build on existing systems and trusted relationships.
- **To design and implement a lightweight, operational Information System** using existing Microsoft tools familiar to users, capable of being deployed in the short-to-medium term to support day-to-day COTS control and innovation workflows, without the overhead of managing infrastructure and low-level coding frameworks.
- **To support integration with related CCIP innovations** and potential future directions of technology advancements, including the On-Water Decision Support System, Manager Dashboards, and reusable digital workflows developed under CCIP-R-02 (Fletcher et al. 2026), enabling automated, real-time data flows from collection to decision-making.
- **To enhance reproducibility and transparency** by enabling the registration of data, processing methods, and provenance, thereby reducing duplication of efforts and accelerating innovation across the program.
- **To provide a pathway for transition** to larger-scale, longer-term information infrastructure under development within the RRAP and RIMReP, ensuring that the outputs of CCIP-R-01 are aligned with broader GBR data architecture goals.

2. METHODS

The design and initial implementation of the COTS Information System was based on an assessment of the needs for on-water operators, researchers, managers, and the wider Innovation Program, a set of underlying design principles, and multiple engagements with management and research stakeholders and end-users. The design and outcomes of the Data Needs Analysis are outlined below. This important process identified key data flows across the Control and Innovation Programs, from collection or initial generation of data (Primary Data), through processing and interpretation (Intermediate Data), to the data used to inform management decisions (Output Data). The design principles, generated from the Innovation Program objectives, are then briefly summarised, before the six core components of the Information System are introduced. Finally, the multiple iterations of stakeholder engagements employed throughout the design process are detailed, and connections to other projects and programs are identified.

2.1 Data Needs Analysis

In November 2021 and May 2022, data requirement reviews were conducted across COTS Control Program managers and the modelling research stakeholders in the CCIP Response Subprogram. These reviews were also augmented with one-on-one discussions with key monitoring and field researchers in the Detection and Prediction Subprograms. Rather than structured surveys or formal interviews, the reviews took the form of targeted consultations, guided by working drafts of the data model and architectural concepts. Participants were invited to reflect on current data workflows, pain points, and anticipated future needs. The purpose of the reviews was to identify the current and target states of the data model of the COTS IS, to facilitate the design of a fit-for-purpose architecture. This process identified several existing and imminent future data sources that the Information System either needed to encompass fully, or needed to be able to index and link to elsewhere. As a result, a high-level data model, i.e. structured representation that defines how different types of data relate to each other and how they are stored, processed, and used, was created for the CCIP that is illustrated in **Figure 2**.

The review revealed three different forms in which data is currently used in the COTS Control Program: 1) Field Program Data that includes data from both the Control Program and other Programs such as the Reef Joint Field Management Program (RJFMP) and Australian Institute of Marine Science (AIMS) Long-Term Monitoring Program; 2) Modelled and Processed Data, including empirically-analysed data and simulations that take input data and process it to produce intermediate and output data; and 3) Data for Decision Making, that is, data used to make decisions based on the insights obtained from modelling and processing. Broadly speaking, data from the RJFMP represented the Input Data phase of the Data Model. Modelling and Processing Data represented the information obtained by adding context and transforming the Input data to create Intermediate Data. The Data for Decision Making represented the set of knowledge that is gained by analysing the data to create Output Data.

There were two primary types of existing data users: 1) COTS Control Program staff and Managers; and 2) researchers, especially researchers implementing models and empirical workflows. Control Program staff and Managers represented the Output Data phase of the

Data Model. Researchers implementing models and empirical workflows consumed Input Data and Intermediate Data to create Output Data. The review also identified future Output Data users, such as Field researchers, who could use data from the Control Program or models to more effectively structure field research.

The review of data needs revealed that for many users, the primary data need was Intermediate Data, rather than Input Data. For example, many models needed COTS density estimates, rather than raw cull data from individual Control Program dives, and many models didn't use field data directly, but rather used parameter estimates derived from field data. The Information System needed to be designed to provide a unified source of processed data to improve efficiency, accuracy, and reusability, as well as enable innovation multiplication across CCIP projects.

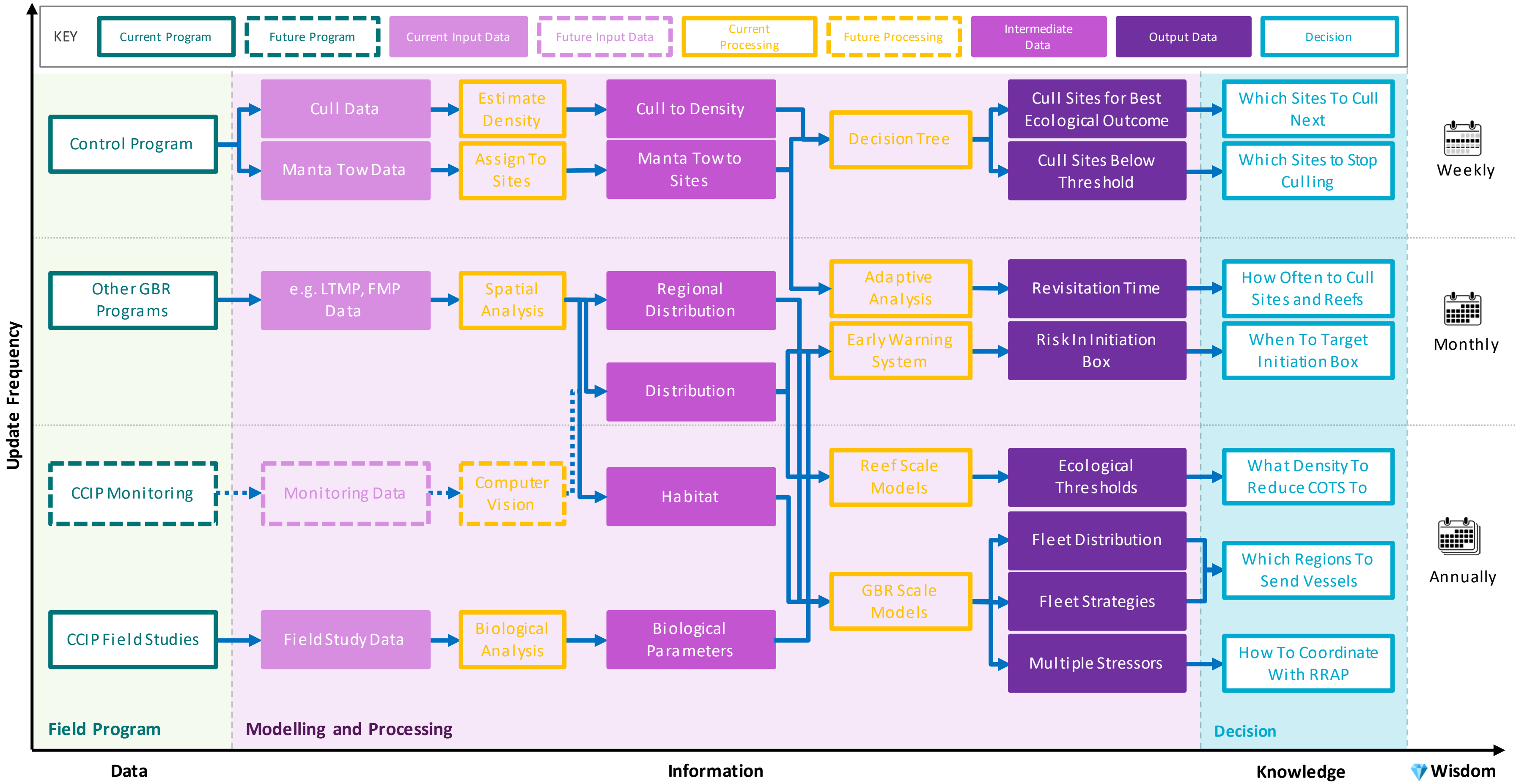


Figure 2. High-level data model of the CCIP. This diagram shows how programs operating in the field, such as the Control Program and other GBR monitoring programs, generate input data that goes through a modelling and processing phase to produce decisions. The timeline shows which data activities are performed on a weekly, monthly or yearly basis. The figure captures a representative sample of data flows, but others exist now and will emerge as the data model enables innovation.

The review also identified that there were two or three distinct timescales over which data was required: 1) “almost real time” – typically within a day or week; 2) monthly to quarterly; and 3) quarterly to annually or longer (**Figure 2**). The only data that was needed in almost real time was that used for tactical decision making within the Control Program. Strategic decision making required only annual or semi-annual data. Somewhat surprisingly, many modelling efforts only required data quarterly or semi-annually, because they integrated new data manually and hence sporadically. However, it was noted that future hybrid modelling methods capable of continuously integrating real-time data into process-based models, such as those being developed under the RRAP M&DS Subprogram, may increase the frequency with which models can ingest new data from quarterly to weekly.

The outcomes of the data needs analysis suggested there were three broad sets of data needs that were related but could be dealt with to some degree separately. First, there were short-term tactical decisions, such as sites to cull, based on Input Data that were updated daily or weekly. These needed to be processed by Empirical Workflows to generate Intermediate Data such as treatment prioritisation maps, to support decisions made on timescales of days to a week. Second, there were **monthly decisions**, such as identifying which reefs to send vessels to in outbreak-prone regions. These relied on some of the same Input Data, but also drew from broader datasets from other research and monitoring programs. Third, there were **long-term decisions**, such as planning future control efforts across seasons or regions. These required integrating Input Data collected on 3, 6 or 12 months cycles, alongside Intermediate Data produced from the daily Control Program Data, to produce authoritative, model-ready datasets. These were used by modellers and other researchers to inform long-term strategic and policy-level Decisions.

This structure suggested that a Data Model addressing the immediate needs of the CCIP Program would be well supported by two main types of workflows (“use cases”): 1) automated workflows generating daily or weekly data updates for Tactical decision making and tracking source data, processing methods and provenance, and 2) a more traditional semi-manual data architecture that incorporated components covering data storage and the metadata required to ensure the quality, interpretability and reusability of that data. There were a small number of data sources and processing steps that sat between these two use cases, requiring regular monthly updates, that could be designed initially as manual processes before being automated as the system matures.

As a result, several design objectives for the COTS Information System were identified: 1) development of several lightweight components to support the automated and semi-manual workflows that could address the immediate needs of CCIP; with an initial emphasis on semi-manual workflows to establish a robust foundation of data quality, provenance, and sharing practices, 2) simultaneously developing a professional culture around data management and sharing, and 3) providing tools to establish a foundation for further digital innovation in future as more workflows become automated and the increased availability of data enables its reuse in new areas.

2.2 Design Principles

In addition to the Data Needs Analysis, a set of Design Principles was identified to target the development of the Information System to the needs of CCIP. These focused on four key principles: 1) supporting innovation, 2) digital as an enabler, 3) best practice data sharing, and 4) maximising interoperability and reuse.

A primary objective of the COTS Information System was to support, speed up, and amplify opportunities for innovation in the way COTS Control is implemented and the research that can help support it. The design of CCIP-R-01 supports this objective, allowing innovation to accelerate as barriers to obtaining data and sharing innovations, knowledge, and insights are reduced. Innovation will be increased when the advances and learnings from one area are easily found, accessed and reused in other areas.

Project CCIP-R-01 aims to leverage digital as a key enabler of innovation in decision support systems. Digitisation speeds up manual processes, increases efficiency, and reduces errors in repetitive processes. In addition, digitised and accessible data can underpin fundamentally new innovations, such as new methods of hybrid modelling incorporating artificial intelligence.

A formal approach to structuring research and management information via an Information System supports best practice approaches to data sharing. The COTS Information System is designed to foster a technology platform and research culture that encourages, empowers and enables data sharing. This is important because the potential of information systems is realised when the data within those systems can be shared across research teams and managers to create linkages between data, derive new insights, and connect insights to drive further innovation. Well-designed data systems are both more reliable and efficient, and can scale to enable future transformation.

Finally, the COTS Information System is intended to provide a platform to maximise the interoperability and reuse across the Program. This will allow CCIP to operate in and contribute to a vibrant ecosystem of interacting GBR-related data sources. Digital innovations in the COTS management system could allow researchers and managers to test, contribute to, and demonstrate the benefits of effective digital transformation to larger GBR efforts. While the system serves as a lightweight, shorter-term solution to support immediate needs, it also lays the groundwork for future integration with larger, long-term information infrastructure efforts.

2.3 Information System Components

Together, the Data Needs Analysis and the Design Principles identified the core capabilities required by the COTS Information System. Based on this, an initial architectural design was scoped based on six key components common to many modern data systems. Components considered included data collection or ingestion systems, storage systems, cataloguing systems, data sharing systems, processing systems, delivery systems and dedicated software clients to help users interact with data. Both the nature of each component required, and the best mode of implementation, such as on-premise or cloud provision, were considered.

The components of primary importance for CCIP were those that could enable efficient data sharing and a trusted source of truth that can be relied on amongst a small cohort of technical users, as opposed to an exhaustive system for general use. This insight enabled decisions about scope; for instance, data collection was identified as being beyond the scope of the COTS Information System because it's generally managed elsewhere – either from the Control Program itself, or in various research projects. Similarly, it was identified that within CCIP, both delivering data into the infrastructure (ingestion) and accessing data from the infrastructure (delivery) were partially managed manually or with a small degree of automation by the technical experts generating or using the data itself. Therefore, complex ingestion or delivery infrastructure suitable for a general web portal accessible to non-technical experts, for instance, were excluded from the COTS Information System. What remained were the components that documented and made searchable the definition and specification of what data were available (Metadata Catalogue), that provided either storage or links to access the data (Data Registry and/or Repository), and that tracked the way data was processed to create new data (Provenance, Process Register and Repository).

Three further considerations guided the design. First, to maximise reuse, compatibility and future integration opportunities, the system needed to support standardised metadata aligned with that being collected in the RRAP M&DS IS and RIMReP DMS. This guided the design of the Metadata catalogue. Second, the system needed to employ a federated approach to data and process storage, allowing users to both store data directly in the COTS IS, and register existing datasets stored elsewhere. Federation is crucial to effective multi-organisational data collaborations. This predicated the need for a "Data Registry" and "Process Register" separate from the "Data Repository" and "Process Repository". Finally, because future workflows are intended to automate parts of data processing, a "Provenance Store" was included in the design to record how intermediate data is generated from multiple input datasets using defined processes. **Figure 3** provides the high-level workflow of the components of the Information System.

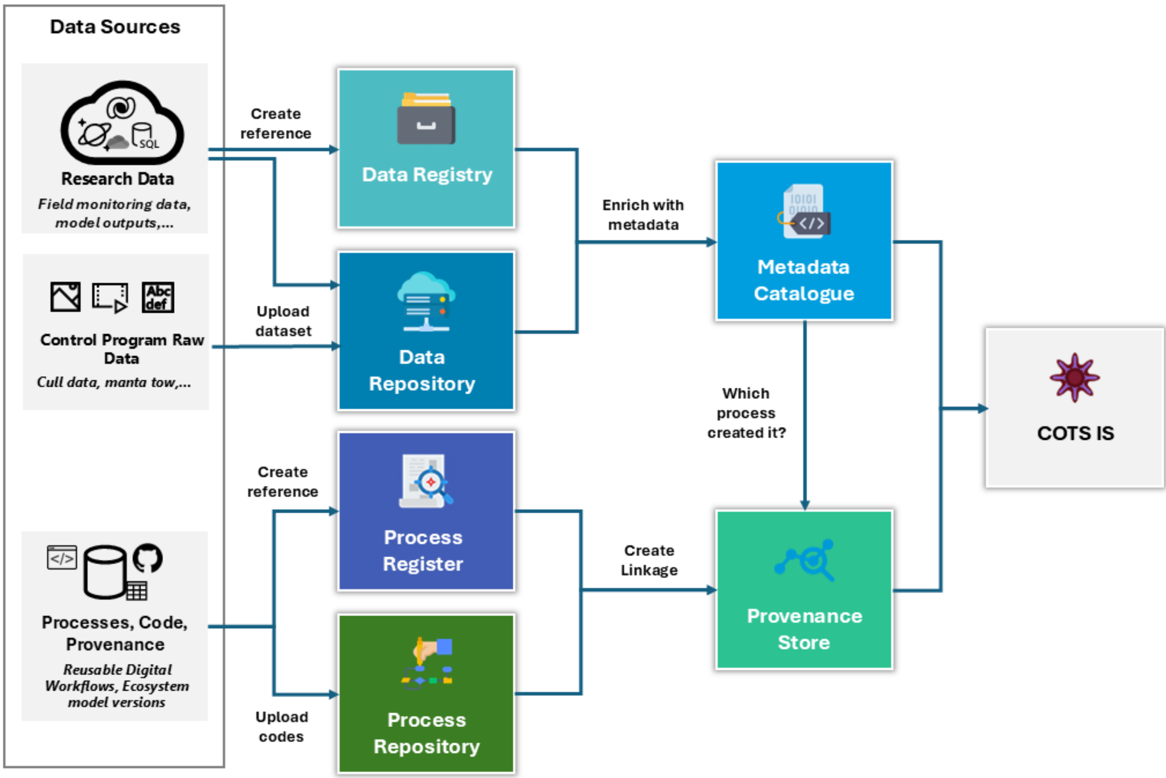


Figure 3. High-level workflow of the COTS Information System (COTS IS), illustrating the flow of COTS research data (e.g., field monitoring data, model outputs and survey datasets), Control Program data (e.g., cull data and manta tow surveys) and processes and workflows into key system components. Data may either be stored within the system or referenced through the data registry, supporting a federated approach to data management and avoiding duplication of original data sources.

The final six components included in the architecture, along with brief definitions are outlined below:

- **Component 1: Metadata Catalogue** – As the volume and diversity of data increases, specific datasets can become difficult to find or understand. A Metadata Catalogue helps COTS decision making and reuse by providing proper data descriptions using a suitable metadata standard, facilitating human and machine search, linked to datasets in a Data Registry (Component 2) and a Data Repository (Component 3). A Metadata Catalogue provides a glossary of terms and a comprehensive description of data elements (entities, attributes and relationships) and their technical and non-technical attributes such as type, format, location, and quality rules, usage rules and security levels.
- **Component 2: Data Registry** – A place to register the existence, high-level definition, and location of COTS-related datasets that may be stored in the CCIP Data Repository (Component 3) or on other institutional repositories. Abstracting the Data Registry from the Data Repository enables a federated approach to data storage, allowing data to be stored anywhere but then accessed from one place, in this case

the COTS Information System. The Data Registry has a search function to discover existing data, learn about it via a link to the associated metadata, and potentially provide access to authorised users through linkage to the Data Repository (Component 3).

- **Component 3: Data Repository** – A structured and central repository for storing datasets required for modelling or decision-support processing, especially for datasets not being stored in other institutional repositories. Data in the repository should be persistent (i.e., not change over time), but be able to be updated through links to other datasets. Access to the Data Repository is currently limited to CCIP researchers and COTS Control Program managers with access to the Information System. In future, it may be possible to make data publicly available.
- **Component 4: Process Register** – A register of authorised workflows or processes that are used to create knowledge and information to inform decision-making. Like the Data Registry, this allows process records to be stored in a variety of formats and locations, while still maintaining a centralised record of the existence of the process to aid Findability, Accessibility, Interoperability and Reusability. Initially, this register will contain records that link to Reusable Digital Workflow processes stored on GitHub as part of project CCIP-R-02 (Fletcher et al. 2026). In future, it could contain records referring to instances of the large GBR Regional Scale models such as ReefMod-GBR and CoCoNet.
- **Component 5: Process Repository** – A repository of transformation workflows or processes that are used to create knowledge and information to inform decision-making, allowing them to be found and accessed. This includes a link to the codebase in the GitHub system or a code repository that is hosted in a widely accessible platform. Initially, this will contain the code describing the Reusable Digital Workflows developed in project CCIP-R-02 (Fletcher et al. 2026).
- **Component 6: Provenance Store** – A store of provenance information linking derived datasets to the data and processes used to generate them. In the first instance, this will contain records linking the derived COTS density datasets intended to be updated regularly to the specific raw Control Program dataset and the specific instance of the Reusable Digital Workflow used to process it. As the number of datasets in the system grows exponentially, and as Reusable Digital Workflows are refined and new versions created, this will allow users to understand how a dataset they might use in their models, field experiments, or decision making was generated.

Rather than develop complex bespoke security and access management, the system was designed to leverage organisational credentials to a cloud-based shared collaboration space.

2.4 Stakeholder Engagement

2.4.1 User Feedback on Information System Architecture

The outputs of the Data Needs Analysis and the proposed Information System architecture outlined above was discussed in a series of CCIP Subprogram online workshops on 31st October 2023 and 1st November 2023, as well as with COTS Control Program managers in a dedicated manager workshop on 3rd November 2023.

Prior to the workshops, the white paper *Proposed Design for the COTS Control Innovation Program Information System* was distributed to invited participants. During the workshops, the proposed architecture and likely use cases for the COTS Information System were discussed and the rationale behind using Microsoft Power Platform as the underlying technology for the Information System was articulated. The main reasons for choosing the Microsoft Power Platform, based on the Program requirement analysis, were: 1) Integration with the existing tools and technologies that are in place across collaboration partners, 2) No dependency on hardware or further services and hidden licensing fees, 3) Low code environment that can potentially lead to higher user engagement rates, 4) Popularity of the Power Platform and ease of finding resources to support it, and 5) Single sign-on security for authentication and user management.

In a workshop setting, participants provided long-form discussion answers to a set of questions around:

- their likely role as a user of the data components of the system; as a data consumer, data producer, or both;
- their likely role as a user of the process components of the system as a process consumer, process producer, or both; and finally
- whether there were any components participants felt were missing from the proposed architecture.

Participants from across most surveyed groups identified that they were likely to be both producers and consumers of data. A notable exception were the on-water COTS Control Program operators, who responded as data consumers. Although on-water operators produce a huge amount of Control Program data, it is delivered automatically to COTS Control Program managers at GBRMPA from the data collection apps before flowing to the COTS Information System. In contrast to data, few researchers expected to be process producers in the short-term. The main use case identified for process consumers was downloading and understanding the details of automated processing workflows for publications. Finally, respondents leading monitoring projects in the Detection Subprogram identified limitations with the proposed Application Programming Interface (API) design and data volumes supported, a known constraint with the system design.

2.4.2 User Feedback on Information System Implementation

Following initial prototype development of the COTS Information System, a workshop was conducted on 14 November 2023 to obtain feedback from users on the user experience of the COTS Information System. The workshop sought feedback on various topics, including complex workflows, usage methods, the spectrum of requirements around the extent to which metadata records cover various datasets, building consensus around the right trade-offs between feature-richness and usability, and an online survey to guide the user experience design.

The participants in the workshop were presented with a set of questions around the socio-technical aspects of the information system, such as search behaviour, device variations, and usage frequency. The engagement was conducted through an online survey that was filled in by the audience within the session. The outcome was clarified through a facilitated discussion with the users.

The list of questions asked during the session include:

- How (what platform) would you usually access the system?
- How often do you anticipate you would access the system?
- How often do you anticipate you would upload a dataset or process in the system?
- When you go searching for a dataset, what is the first step?
- When you have found a dataset you think you are interested in, what information about it do you want to find first?
- How important is it for you to have access restriction on your datasets in the system?

The responses to the survey are attached in Appendix A.

The users highlighted that a common use case was uploading a series of multiple files within a dataset. This insight was used to refine the manner in which data files were linked to Metadata and Data Registry records. A second common use case identified was uploading one-off datasets. This insight resulted in the user interface design being refined to provide more guidance to occasional users. One of the requirements highlighted within the workshop was the ability to store metadata about a dataset that linked to datasets hosted in external cloud storage systems. This was functionality already supported by the Data Registry architecture.

3. RESULTS

The initial implementation of the COTS Information System provides a set of functionalities aligned with the needs identified through the Data Needs Analysis, the Design Principles, and the Architecture. To implement the COTS Information System efficiently, the existing productivity tools within Microsoft Office 365 were leveraged, including Microsoft Teams for capturing user interactions and Microsoft Power Automate for automating the way data flows. The following subsections outline the components of the COTS Information System and describe the approach that has been adopted to implement these components. **Figure 4** shows a high-level view of the implementation.

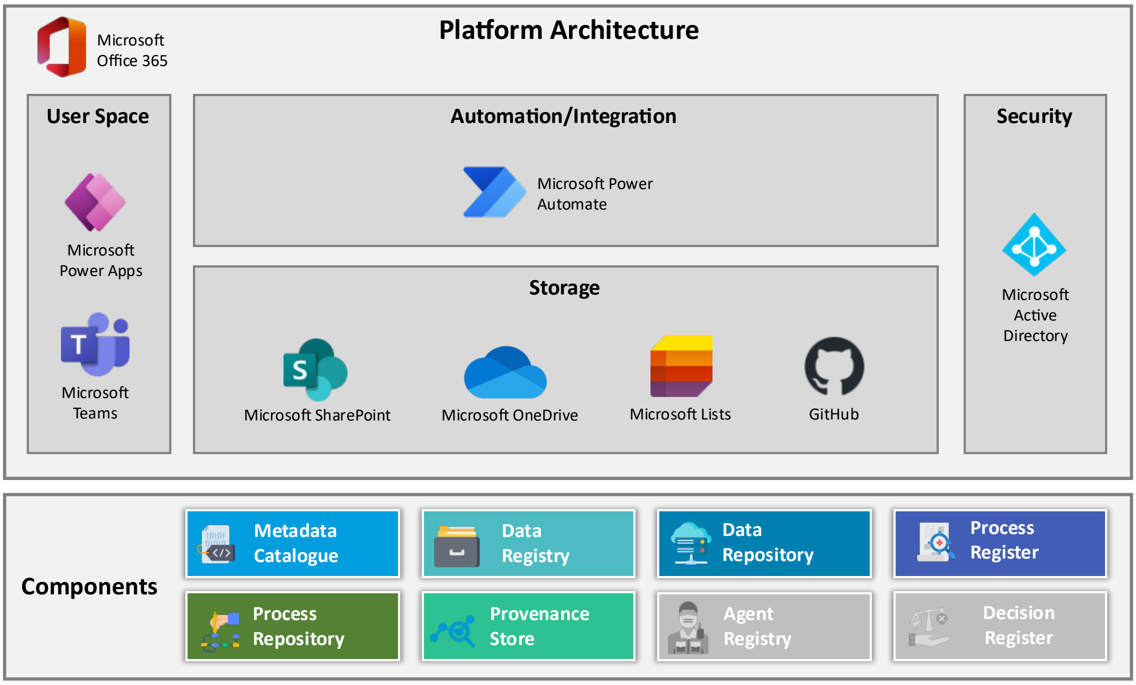


Figure 4. The components of the COTS Information System, with the technologies that have been used to implement them. The technology stack is a subset of the Microsoft Office 365 subscription, where the user space tools are available to all corporate users and some of the more technical tools are only available to users with a developer license. The Agent Registry and Decision Register are not in the scope for the COTS Information System, but are included in reference to Information Systems being developed in other GBR research programs.

3.1 Component 1: Metadata Catalogue

The Metadata Catalogue (**Figure 5**) stores metadata fields that describe each dataset using a consistent standardised format. This ensures that datasets are properly described and findable. In addition, the metadata catalogue provides the ability to search within the existing catalogue using various levels of details in the form of a basic search and advance/detailed search.

The Metadata Catalogue was implemented using a set of standard templates that are consistent with the RIMReP DMS. This was done to maximise compatibility and user experience across GBR Information Systems, as well as provide future migration pathways for the integration of Information Systems. The feature is implemented using interactive forms within Microsoft Power Apps, and cloud-based relational storage within Microsoft Lists when uploading data to the Data Registry or Data Repository. Therefore, the Metadata Catalogue is directly linked to the Data Repository and Data Registry.

Microsoft Power Apps features interactive forms that allow the developer to create and share online forms to capture user inputs in a structured format and store it in a Microsoft List. Microsoft Power Apps supports the Metadata Catalogue by establishing a standard structure to the metadata, enforcing data validation rules to enhance the quality of the metadata that is being captured, and storing the metadata in a structured format that is easy to search and access. The structured metadata is stored using Microsoft Lists, which is an Office 365 service to store structured data with the ability to select data types, and smooth integration with other Microsoft products such as Power Automate for automation.

Two forms of search have been implemented—basic and advanced. Basic search offers a user-friendly, simple yet rich experience to find datasets by accessing all metadata fields. The advanced search offers an interactive search capability to address complex search scenarios. The input of each search form is linked to a search function, that uses the built-in “Search” function within Power Apps.

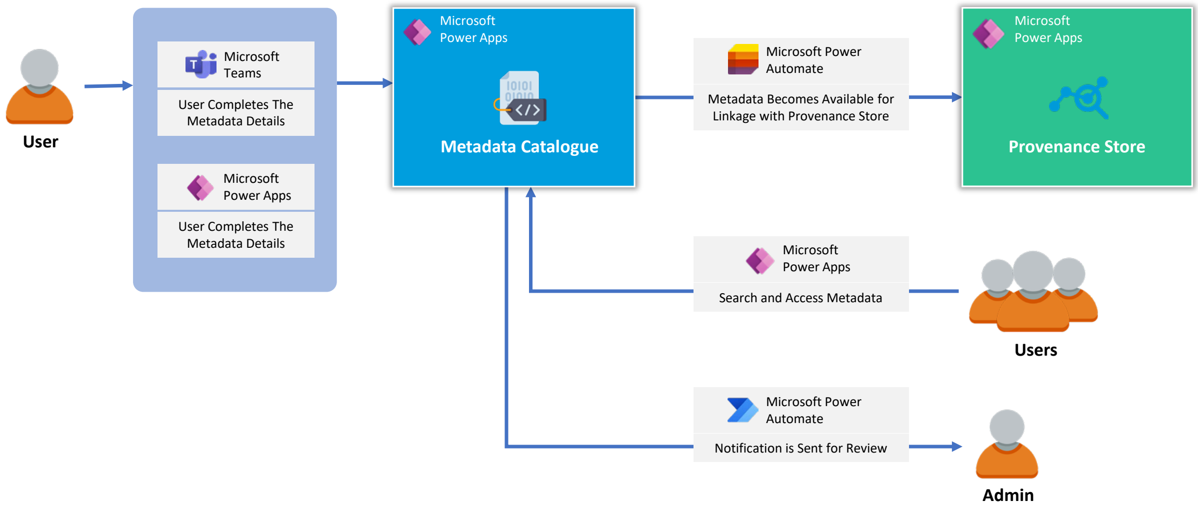


Figure 5. High-level implementation diagram of Component 1: Metadata Catalogue.

3.2 Component 2: Data Registry

Since a significant number of datasets are stored on-premise or in cloud tenancies that are only accessible to certain management or research organisations, such as GBRMPA Eye-On-The-Reef (EOTR) repository that hosts the Control Program Data. The Data Registry (**Figure 6**) is provisioned to store links and metadata descriptions for external datasets without the need to duplicate the storage of the dataset itself. The Data Registry items can be searched through the basic and advanced search functionalities, which enhances the findability of siloed datasets. This increase in the findability of external datasets was a key implementation goal for the COTS Information System to overcome the inefficiency of organisationally siloed data. In addition, there is provision for access requests, where a user can request access to a certain Data Registry item, thereby notifying the owner of the dataset via email to negotiate means of dataset delivery.

The Data Registry is implemented using a set of standard templates that are consistent with the RRAP M&DS IS and RIMReP DMS systems, to ensure consistent user experience and future data migration options. The Data Registry (**Figure 6**) is implemented using Microsoft Power Apps, Microsoft Lists and Microsoft Power Automate to ensure automatic quality checks and linkage to the Data Repository are validated. The Data Registry also features a user-friendly searchable interface for stored records that can be integrated into Microsoft Teams.

Microsoft Apps supports the Data Registry by providing a user interface to enter and update the data entities that exist within the COTS Information System, as well as other functions such as validation, data type checking and data entry auto-complete. This ensures a consistent set of information fields are recorded for each data entity. In addition, Microsoft Lists provides the ability to store the information in a structured way and maintain a linkage with other products within Microsoft Office 365, such as the search interface. Microsoft Power Automate is used to trigger the execution of automated workflows when a new entry is created in the Data Registry or an update is made to an existing entry, or when a dataset is added to the Data Registry.

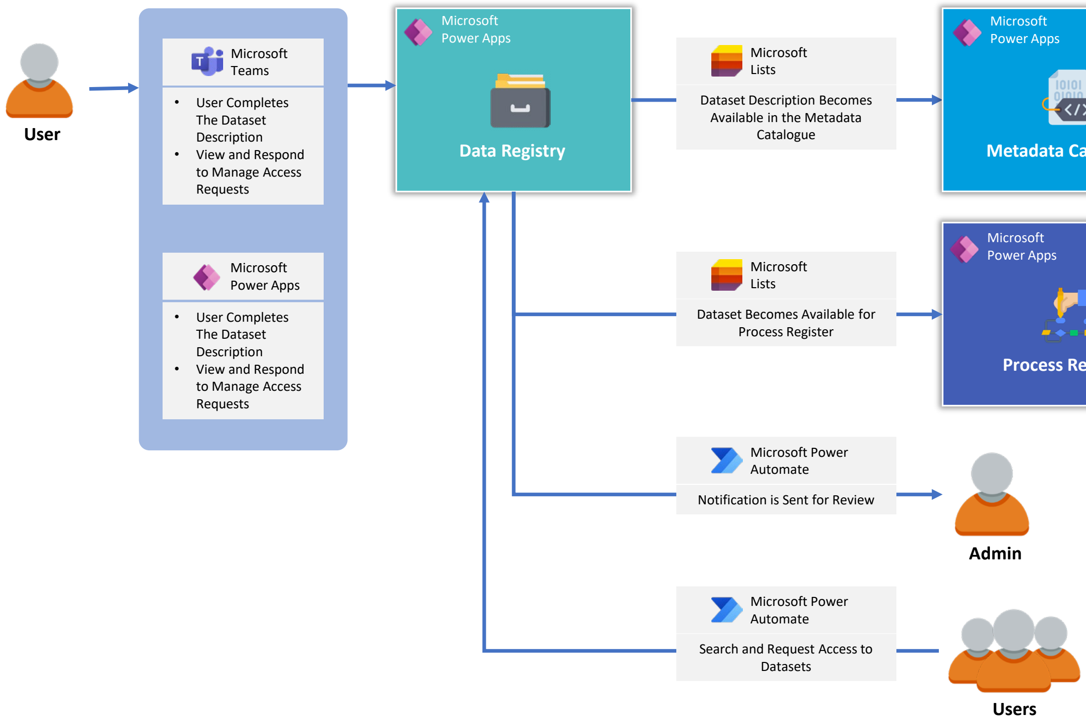


Figure 6. High-level implementation diagram of Component 2: Data Registry.

In addition to the development of a link storage capability for the Data Registry, this component features a basic and advanced search functionality, accessed by the user within the Metadata Catalogue, as well as an access request workflow. The search functionality for the Data Registry is based on the Microsoft Power Apps standard library "Search" function. The access request workflow within the Data Registry is based on interactive Power Apps Forms, and Microsoft Power Automate to create integration with email service and other request workflow components.

3.3 Component 3: Data Repository

The Data Repository (**Figure 7**) enables users to upload moderately sized datasets (up to 128MB) within the platform and attach metadata to it. Larger datasets can be linked to the Data Registry from an external repository. In addition to the storage of the datasets and metadata, the Data Repository features search functionality via the Metadata Catalogue (Component 1) to increase the findability of datasets, increasing data reuse and collaboration. Every dataset that is shared within the Data Repository can be made available for other users to find and download, and it serves as the intended source-of-truth for a dataset.

The Data Repository is implemented as a Microsoft cloud storage using Microsoft Lists and Microsoft Azure Blob Storage, integrated in Microsoft Teams to be accessible through user space. Access to the Microsoft Lists and OneDrive folders is protected using a standard corporate identity management solution, which offers an authentication gateway through Microsoft Active Directory. Microsoft Power Automate is used to perform automatic encryption of private data. In the short-term, close collaboration with the GBRMPA team will identify optimal solutions for interim Control Program data upload that maximises automation and minimises manual export and storage while facilitating access and maintaining security. In future, this process is expected to become completely automated through future API integration with GBRMPA's new Control Program database, which is under development to modernise how raw field data is stored and managed. Linking directly to this new database will reduce manual handling, improve data timeliness, and enhance interoperability with other systems.

Individual research teams may store their intermediate data outputs directly in the Data Repository, in which case the process of uploading it will automatically link it to the Data Registry and metadata entry via Power Automate workflows and linked Microsoft Forms. Alternatively, they may store their data on their own organisational repositories and provide appropriate metadata and links to access the data within the Data Registry. The Data Repository and Data Registry are linked together through the Metadata Catalogue, which acts as the main interface for discovery and access. When a dataset is uploaded to the Data Repository, a corresponding record is automatically created in the Data Registry and linked to detailed metadata in the Metadata Catalogue. This ensures that users only need to search via the Metadata Catalogue to find and access datasets, regardless of whether they are stored internally or externally.

The use of Microsoft Lists storage provides the ability to seamlessly share datasets across teams and ensure dataset storage challenges are avoided as it offers integrated version management, security, archive and backup to government standards. This helps avoid dealing with complex infrastructure to manage large volumes of data. **Figure 7** shows how the user interacts with the Data Repository.

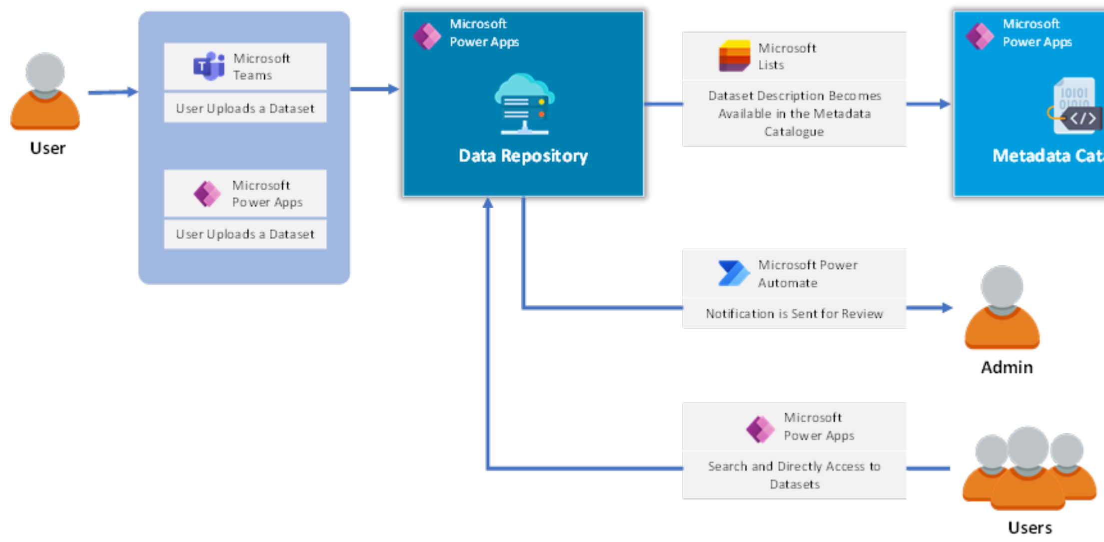


Figure 7. High-level implementation diagram of Component 3: Data Repository.

In addition to the storage capability of the Data Repository, the Information System offers a user friendly basic and advanced search functionality that is embedded in the Metadata Catalogue to discover datasets. Once data is uploaded, users will be able to browse datasets within the Data Repository and download the associated files by opening each dataset. Once a dataset is created, users can be notified and attempt to access the dataset.

3.4 Component 4: Process Register

In addition to primary datasets, the scientific processes and code bases used to process and gain insights from primary data to create intermediate data are central to the operation of the COTS Control Program and the innovation enabled by CCIP. However, like data, some of the processes and source code used to generate important intermediate data and inform decisions may be known to only a few researchers, and hosted in private source code management systems, local computers, or other on-premise storage that is not easily accessible. To address this, the Process Register (**Figure 8**) is designed to store a link to the processes / source codes that have been used to produce insights / datasets. This means that the relationship between the process and the input and output datasets (or provenance) is also an essential piece of information to capture at the time of creating Process Register entries.

The Process Register was developed using interactive forms within Microsoft Power Apps to capture user interactions, and Microsoft Lists to record the details of the documentation around processes. Each registered process is linked to the code repository (such as Github or BitBucket version management platforms) with a new major version of code for each Process used to generate derived data. The metadata fields that are used to describe a process follow a standard template that is consistent across all processes within the Information System. The Process Register will allow users to perform basic and advanced searches of existing processes, or pieces of computer code used to process data, in a similar manner to the role the Data Registry plays for datasets. This will increase the findability and accessibility of processing workflows being developed across CCIP, increasing transparency and enabling innovation multiplication by allowing others to reuse code or concepts. There is an access request workflow employed within the Process Register to ensure that researchers and managers have a point of contact to obtain access to processes.

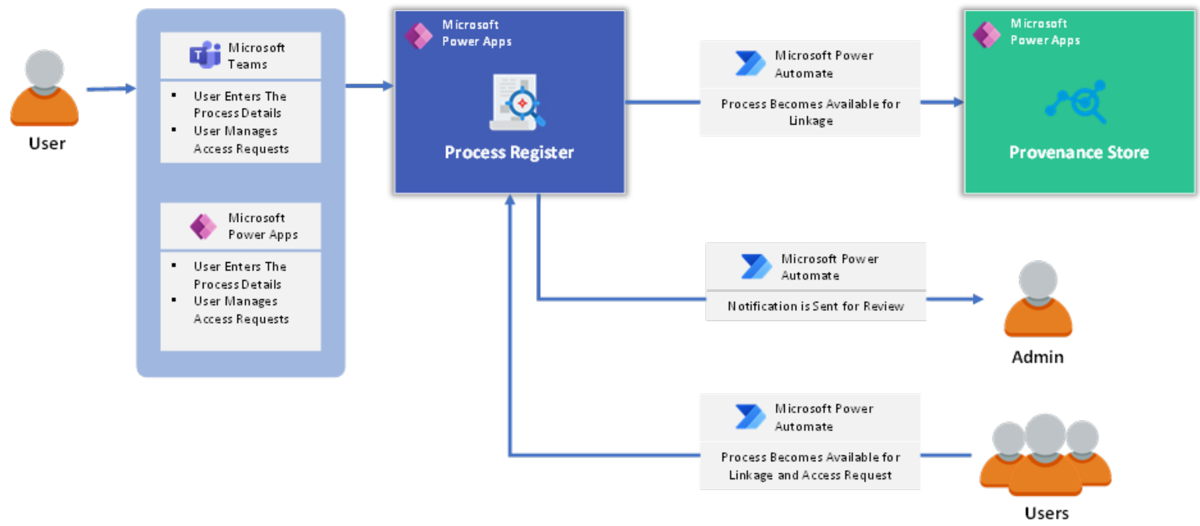


Figure 8. High-level implementation diagram of Component 4: Process Register.

Microsoft Lists is a structured data storage feature of Microsoft Office 365 for enabling information exchange, task tracking or joint collaboration, data validation and quality checking. The use of Microsoft Lists offers the ability to maintain a uniform structure for the data transformation processes with the ability to perform validation. In addition, processes can be directly linked to the Data Registry and Metadata Catalogue, hence consistency and validation rules are automatically applied, which reduces the potential for user entry errors. The search functionality within the Process Register uses the Power Apps built-in “Search” functionality that can search within a Microsoft List using various search constraints.

3.5 Component 5: Process Repository

In addition to the Process Register that can store links to the processes, the Process Repository (**Figure 9**) is provisioned to store the processes in the form of source code and other artefacts. The Process Repository streamlines the findability and accessibility of processes by providing direct access to the Information System users. The search functionality within the Process Repository features both a basic and advanced search functionality for users with different levels of technical skills.

The Process Repository was developed using interactive forms within Microsoft Power Apps, Microsoft Lists and Microsoft Power Automate. This provides the ability to store a wide range of compressed code repositories and share them across the users of the Information System as well as linking them to the input and output datasets. Once a repository item is created in the Information System, a Microsoft Power Automate workflow is initiated to ensure that relevant users (registered owners, responsible users, and system admins) are informed and can benefit from using it. There is an option to migrate the uploaded processes into GitHub using Microsoft Power Automate and Microsoft Logic Apps.

The Process Repository also features a basic and advanced search functionality that enables users to drill down existing processes in the system and find them. Once the user clicks and opens a process in the Information System, it is possible to view additional information, such as input and output datasets, relevant processes and any related provenance records. The search functionality within the Process Repository is based on the built-in "Search" function within the Microsoft Power Apps, and the relational model between the processes and input / output datasets is enabled using Microsoft Lists.

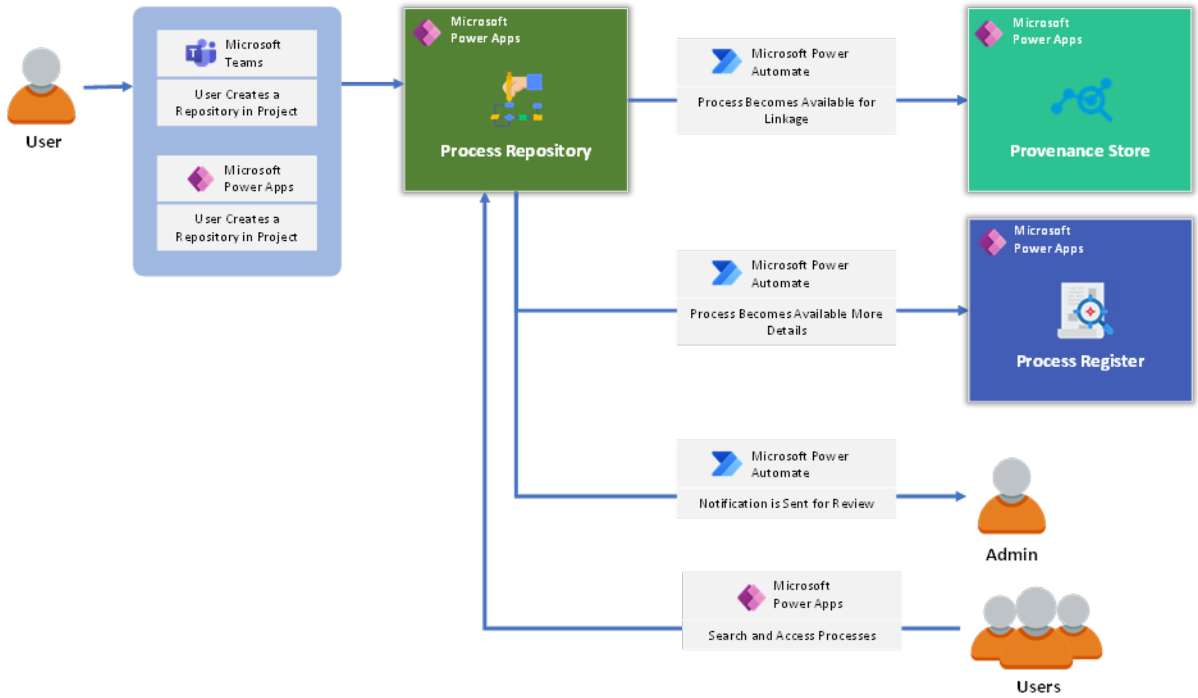


Figure 9. High-level implementation diagram of Component 5: Process Repository.

3.6 Component 6: Provenance Store

Provenance is the intersection between data and processes, which enables tracing of output datasets and the insights generated from them to inform decision making, back to the processes and input data that was used to generate them. The tracking of provenance is extremely important in research and innovation settings, both so decisions that are made based on scientific results are well-documented and supported, and to enable future innovation by reviewing and refining information flows. The Information System enables the tracking of provenance by enabling the connection between the processes (in both Repository and Register) and the datasets (in both Repository and Registry).

The Provenance Store (**Figure 10**) was developed using a combination of Microsoft Lists, Microsoft Power Apps built-in functions and Microsoft Power Automate to record the way Processes are used to transform Data to create new Data. The lists store a series of records that link input datasets, through a specific process with a specific implementation at a specific point in time, to the output datasets generated through that process. In its raw form, a technical user can use this information to understand exactly how a processed dataset was derived, dramatically increasing its future reusability. The lists also provide a built-in integrity checking method by creating linkage between processes and datasets.

Vitally, this system provides a powerful foundation capable of supporting significant innovation beyond this basic use case of manually linking datasets and processes. Because the metadata, data, process data and provenance data are all machine readable via an API, future digital innovations built on this system could allow automated workflows and artificial intelligence approaches to automatically read metadata and provenance records for datasets, run or even refine processing codebases to improve model performance, and automatically generate the metadata and provenance records for new derived workflows.

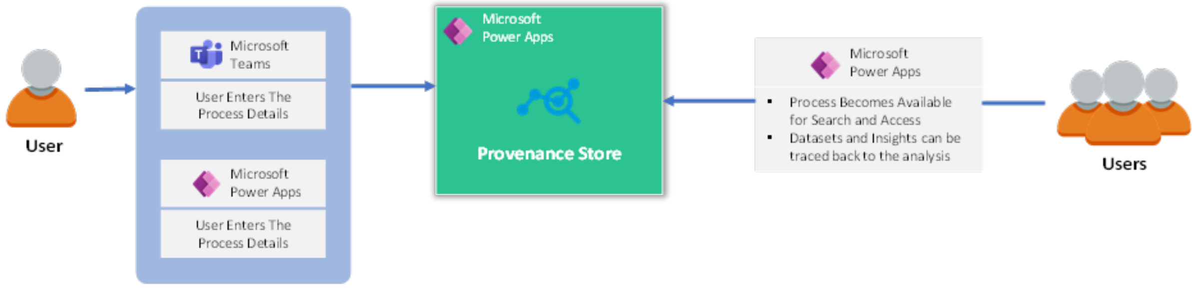


Figure 10. High-level implementation diagram of Component 6: Provenance Store.

The use of Microsoft Lists enables a validated linkage between the Process Register and Data Registry. This means that an entry within the Provenance Store can be traced back to access the input dataset, its definition and metadata.

3.7 Tools and Technologies

As referenced in each of the component descriptions above, the platform architecture consists of a suite of products that are available within the corporate Microsoft Office 365 subscription. The following list describes each product that has been used, with the rationale where appropriate:

User Space: A platform that is used by a user to interact with the Information System and utilise the features of the system. This includes forms, tables, lists and files to perform various activities such as storing data and metadata records, as well as searching the metadata and process catalogues. Microsoft Forms is the entry point to the Information System, where a set of forms are present for data entry. Microsoft Teams is used as an interface to present all the functionalities of the solution.

Automation / Integration: Microsoft Power Automate is used by the COTS Information System project team to automate routine tasks such as validation, notification, and data transfers. This part of the system is not directly accessible to end users.

Storage: Microsoft SharePoint is used as a platform to create a structured portal that includes access to the tools, as well as how-to documentation for the platform. Microsoft Lists is used to store structured and semi-structured data such as metadata, the Data Registry, and potentially some of the datasets. It is noted that Microsoft Lists is built on top of one of the components of Microsoft SharePoint, i.e., Microsoft SharePoint Lists; however, Microsoft Lists offers a more versatile user experience with more data representation options. Microsoft OneDrive is used as a cloud storage platform for shareable datasets. Finally, GitHub Project is used to store the code repositories for processes that have been used for data transformation.

Security: Microsoft Active Directory is the corporate identity management solution that provides the user authentication service for users' access to the platform.

4. DISCUSSION AND OUTPUTS

The COTS Information System (COTS IS) is intended to be a crucial step toward streamlining access to data and increasing innovation opportunities across COTS management and research efforts. It is also a key enabling technology for major innovations from several projects across CCIP. For instance, project CCIP-R-02 (Fletcher et al. 2026) is designed to build on the COTS IS being developed as part of CCIP-R-01 to enable three major innovations, around Reusable Digital Workflows, Manager Dashboards, and the On-Water Decision Support System.

As outlined in the Methods (Section 2), the COTS IS was designed based on an analysis of data and process needs informed by workshops with COTS Control Program managers and CCIP researchers. The Results (Section 3) described how the Information System was implemented using components from the Microsoft stack, notably Office 365 and Power Platform. Below, common workflows for the Information System are described in detail, including screenshots of the COTS IS in use. This is followed by an assessment of the relative performance of the design and implementation of the COTS IS.

4.1 Using the COTS Information System

The Information System can be made available to the set of intended users (COTS researchers and managers) via Microsoft Teams or the Microsoft Power Apps dashboard. To access these platforms, a user needs to authenticate using their guest credentials, which are generally tied to their organisational credentials when the invitation to access the Information System is sent. Users need to be added as a guest to the organisational tenancy that hosts the application in their Microsoft Office 365 platform (currently CSIRO). **Figure 11** shows the interface of the application in both Microsoft Teams and Power Apps.

The user interface consists of various components to access the functionality of the Information System, from creating new metadata records for data or processes, to searching for, understanding and accessing those data and processes. The user interface provides access to basic and advanced searches within datasets and processes, and provides a workflow for managing access requests to datasets that are listed in the registry and stored elsewhere. The top level of the user interface is divided into four sections: Datasets, Processes, Provenance, and Profile, that provide access to more detailed user interfaces within each of these categories. The following sections describe various components of the application.

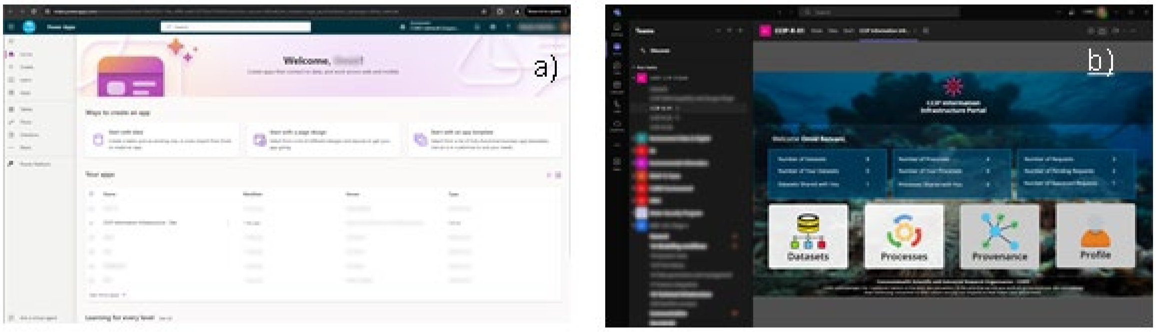


Figure 11. Information System home page: a) within Microsoft Power Apps dashboard; b) within Microsoft Teams platform.

4.1.1 Dataset and metadata entry

Users click on the “Datasets” item in the main interface page to access the metadata entries for dataset repository and registry items. Within the Datasets page, a user can upload a metadata item, explore existing dataset items, or manage dataset access requests. **Figure 12a** shows the entry page of the datasets.

Users need to complete a single form to create metadata for a dataset repository or registry item. Once the user clicks on “Upload Dataset”, they will be presented with two options to either select an existing metadata entry as a template or start a metadata entry from a blank item. To select an existing metadata item as a template for streamlined entry, the user can search within the existing Metadata Catalogue (via Explore Datasets) and select an item by clicking on the arrow icon. **Figure 12b** shows the initial page of the metadata entry process.

Once the user enters the metadata entry workflow, the last page (**Figure 12c**) is dedicated to select whether the metadata is for a dataset registry item or dataset repository item. To add the metadata for the dataset registry, the user must enter a link for the dataset, and to add the metadata for the dataset repository, the user must upload the files that are associated with the item.

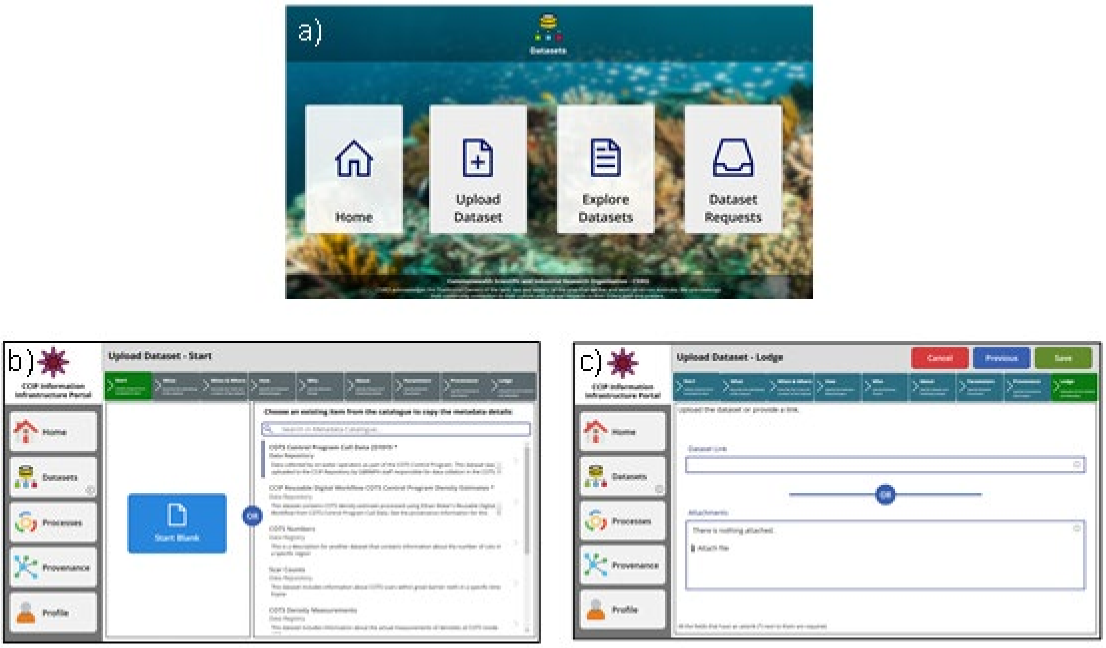


Figure 12. Dataset and metadata entry. **a)** shows the entry point of the Metadata Catalogue. The user can upload a metadata item, search and find existing items, or manage access requests, **b)** shows the first step of the upload dataset form, which requires the user to select either an existing metadata entry as a template, or a blank form, and **c)** shows the last step in creating a metadata entry, which is to specify whether the metadata is for a dataset registry item stored elsewhere, or a dataset repository item stored in the COTS Information System.

4.1.2 Data search

The Information System provides the ability to search within the dataset catalogue using a basic search function and an advanced search function. The basic search function is intended to provide a simple, yet inclusive search function that is easy to use, by searching a term or phrase within all fields of the metadata items. The advanced search function is designed for more specific searches, as the user is provided with a form to choose specific search terms for each metadata field. **Figure 13** shows the different views of the search functionalities for the Metadata Catalogue.

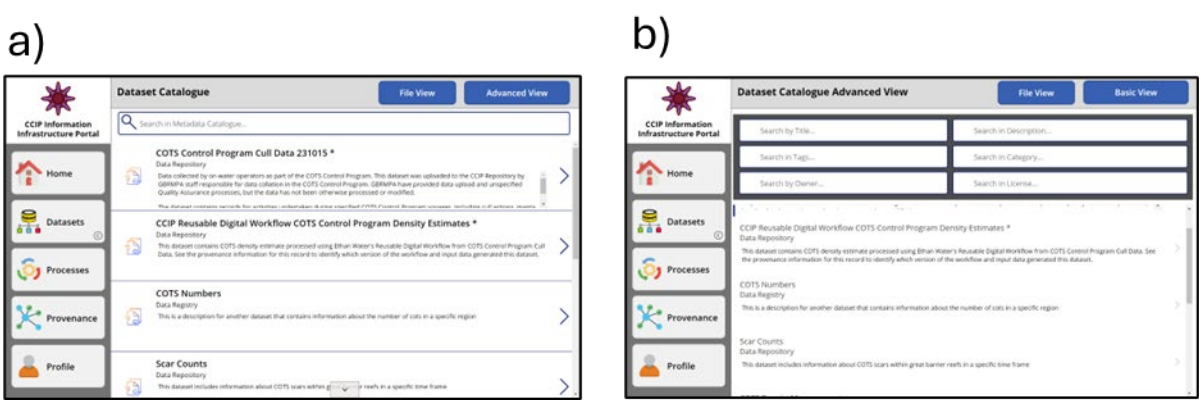


Figure 13. Metadata search function. **a)** shows the basic search function, which is simple, yet effective. It searches within all fields of the Metadata Catalogue, and **b)** shows the advanced search function, which is designed for more specific searches. It searches specific terms within each field of the metadata catalogue.

4.1.3 Dataset Access Request

While the items in the Data Repository are available to all the of the users who have access to the Information System, the items in the Data Registry may not be directly available via Information System. To request access to a specific dataset within the Data Registry, a user first needs to enter the designated page for that dataset. The first view of the metadata for each dataset in the registry includes details of each field and a button to show more details. A user can request access to a dataset by clicking the “Request Access” button. **Figure 14a** shows the first page of the metadata description for a dataset in the registry.

Once the user clicks on the “Request Access” button, a form appears that requires the user to provide details around the intentions of using the dataset. The system will then send the owner of the dataset an email message to notify them of a new access request.

The owner of the dataset can view all the access requests in their associated email address, or within the access request page. The page is usually filtered by the status of the requests, therefore, the user needs to always check if the right filter is applied. Once the dataset owner finds a request, they can respond to it by accepting or rejecting it.

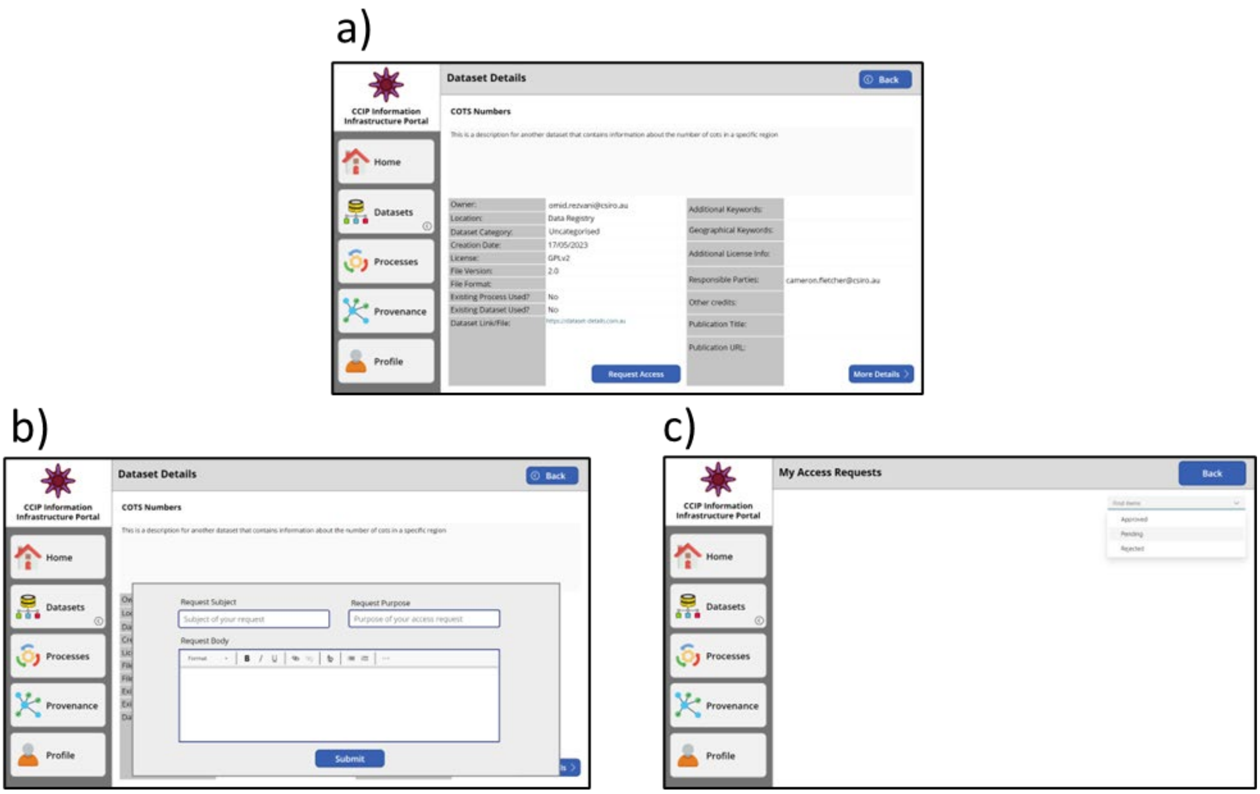


Figure 14. Metadata View and Dataset Access Request Pages. **a)** shows the metadata description of a dataset in the registry, where the user can request access by clicking "Request Access", or view further details of the dataset by clicking on the "More Details" button, **b)** shows the Dataset access request form, and **c)** shows how Dataset requests can be managed by accessing the "Access Requests" page and filtering based on the status.

4.1.4 Processes (Entry and Search)

The user experience to access, upload, search and request access to Processes is designed to be similar to the experience for Datasets, so it is presented briefly here. Users can access metadata entries for Process Repository and Process Register items by clicking on the "Processes" item on the main interface page. Within the processes page, a user can upload a metadata item for a processing workflow, explore existing metadata items, or manage process access requests. **Figure 15a** shows the entry page of the processes.

The user can create a new process metadata entry through the "Upload Process" item. They can either select an existing process entry as a metadata template or start a process entry from a blank item. Existing processes can be selected as a template using the unified search of the provenance catalogue and selecting the chosen item by clicking on the arrow icon. **Figure 15b** shows the initial page of the process entry workflow. As with data entry, the last page of the process entry workflow allows the user to specify whether the item belongs to the Process Register and is stored elsewhere, or the Process Repository for storage within the COTS IS. To add an item to the Process Register, the user must enter a link for the process. To add an item in the Process Repository, the user must upload the associated files.

The COTS IS provides the ability to search within the process catalogue using a basic search function. While the Metadata Catalogue features a basic search and an advanced search, the process catalogue only features a basic search functionality that allows users to search all process records across all metadata fields.

Users can request access to a Process in a similar manner to the data request workflow. To request access to a specific Process within the Process Register, a user enters the page for the Process after browsing to the item via the Explore Processes page, or via a search result. On the first page of the record view, the user can choose to see "More Details" or "Request Access" via the appropriate button. When a user requests access, a form is displayed to provide a reason to support their request for access. The system sends the request to the owner of the process via email. Process owners can view all access requests for their processes via email, or within the Access Request page of the COTS IS. **Figure 15e** and **Figure 15f** show the relevant screens in the user interface.

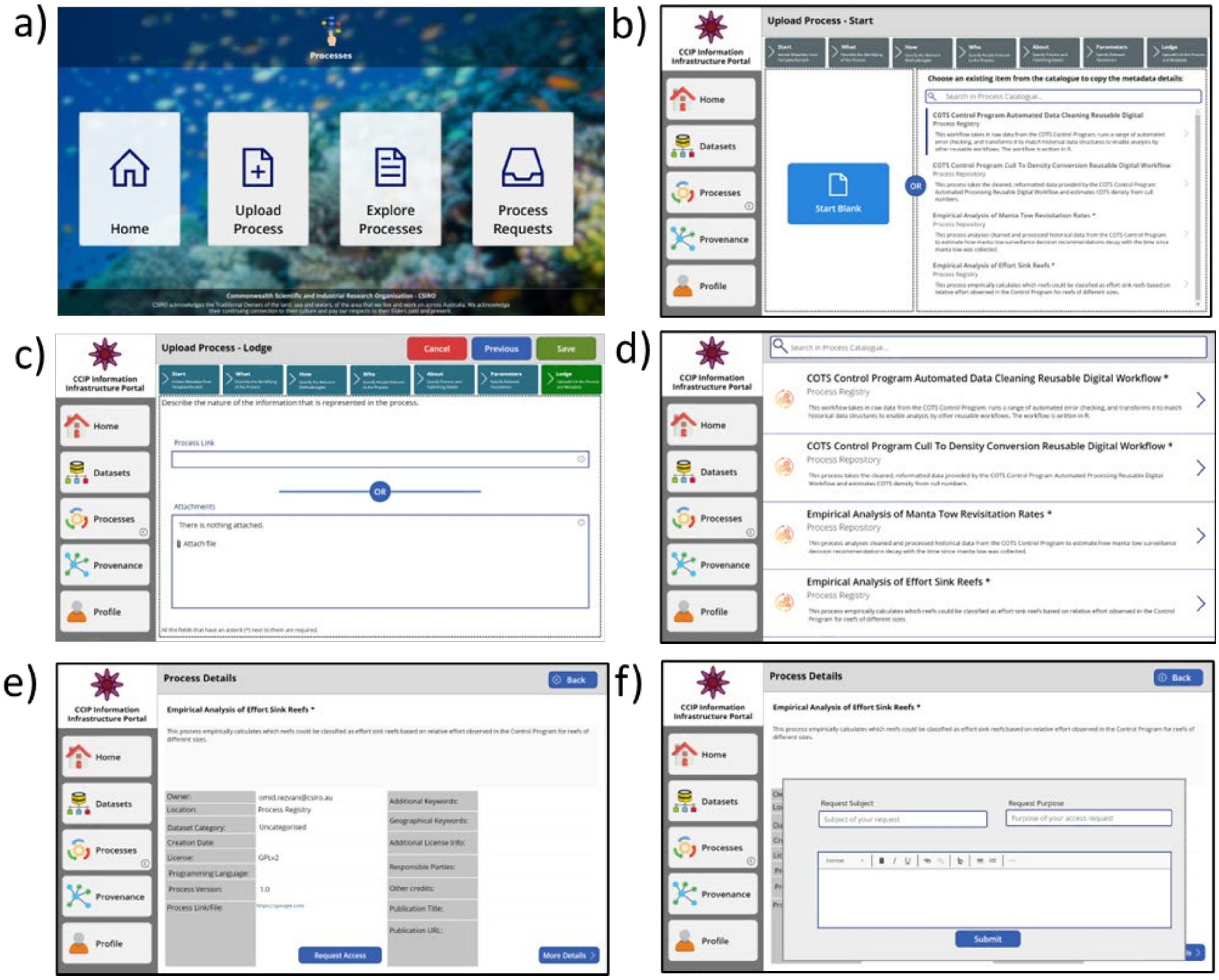


Figure 15. Process entry and search. **a)** shows the entry page of "Processes", which provides the user with the option to upload a new process, search within existing processes or manage requests to access a process, **b)** shows the first step of the Upload Process form, which is to select whether to use an existing process as a metadata template or begin with a blank form, **c)** shows the last step of the Process upload, which is to select whether the process is stored in the COTS Information System within the Progress Repository, or linked to an external location via the Process Register, and **d)** shows the operation of the unified search function, which is similar to the basic search for data in that it searches all fields within all processes in the catalogue. Figures **e)** and **f)** show the workflow to request access to a Process, which is similar to the process for requesting access to a dataset. The "More Details" button can be used to access further details of the process, and the "Request Access" button can be used to request access. The form allows the user to explain why they require access.

4.1.5 Provenance

Provenance connects input datasets, computational processes that are used to analyse an input dataset, and an output dataset, which could be insights or derived information, that has been generated as a result of the process. Provenance provides a powerful tool to trace insights and information back to the analysis and source data, which helps justify decisions that are driven by insights and data. The “Provenance” component of the COTS IS shows the linkages between datasets and processes in a simple tabular format. The user can traverse provenance information by, for instance, viewing the input datasets for a specified process; if one input dataset is of particular interest or importance, the user can click it to see its metadata. This could include information about whether the input dataset was itself generated from another process, in which case the user can view that provenance relationship and the input data and processes that were used to generate the dataset. In future, this component of the user interface will be updated to include a more advanced visual network showing how processes and datasets are linked. It will also feature advanced API access so that systems and tools can automatically explore and use this provenance information. In future, this kind of capability could enable digitally transformative technologies like artificial intelligence for hypothesis generation and uncertainty analysis.

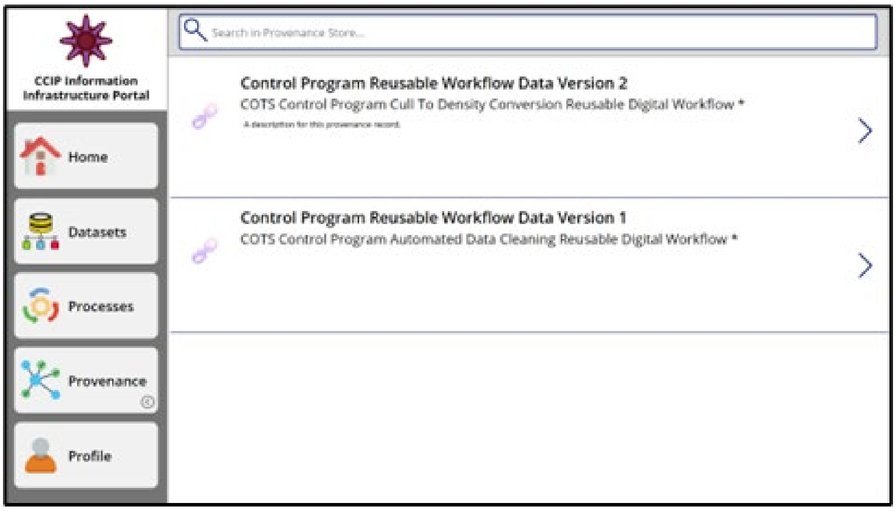


Figure 16. Provenance shows the linkage between datasets and processes.

4.2 Reflections

The implementation of the COTS IS achieved many of the design objectives established at the beginning of the project, and following user engagement and the data needs analysis. However, there were also learnings and opportunities for further refinement. Below, we review the relative performance of various design choices implemented.

The COTS IS was designed with a lightweight implementation using low-code off-the-shelf components of the Microsoft stack with the goal of minimising development time, maximising compatibility with stakeholder platforms, and providing users simple and familiar access methods. Overall, this worked well, with the build progressing quickly, leveraging existing organisational resources, with integration into Teams, and availability as a standalone web application. However, this also introduced some complexities and limitations. Most notably, Microsoft employs a complex licensing system for Power Apps that requires the correct license on both server and client. Although most organisations with enterprise licensing of the Microsoft suite will have access to Power Apps, for those that do not have it included by default, incorporating a single user license into the mix becomes complicated.

Many of the other characteristics of the Microsoft-centred implementation could be considered both features and constraints, depending on the specific need. For instance, file storage is easily integrated into organisations' SharePoint systems, making it straightforward to manage within existing IT environments. However, this also means that storage policies, such as quotas and access restrictions, are controlled by the organisation, which can introduce limitations that are challenging to address. Additionally, some files are stored as attachments within Microsoft Lists, which imposes a maximum file size limit of 128 megabytes. This limitation can be addressed by storing larger files in external storage locations (for example, in institutional repositories or Azure Blob Storage) and then linking to them through the Data Registry. An example of this approach is the linking of large raw COTS Control Program datasets, which are too large to attach directly. Similarly, the Power Platform provides an easily accessed API platform which is good for simple access to the system. However, more advanced API solutions require bespoke development in a system not geared to provide complex APIs. This limitation would mainly occur if future projects require complex, large-scale automated integrations (for example, real-time data streaming into advanced external modelling systems). For the current scope of the COTS Information System, this is not a major issue, as most integrations are expected to involve simpler, periodic data exchanges rather than continuous automated operations.

A significant simplification of the COTS IS was the use of platform-level credentials. This was an explicit design choice after the User Needs Review, meaning that anybody that had credentials to access the COTS IS system could access any file stored on the system. This approach was considered optimal to encourage data sharing and reuse amongst COTS researchers and managers, and was easy to implement by leveraging organisations' Microsoft single sign-on process. However, it made it impossible to implement per-file granularity for security and access credentials. This is an issue for some types of data incorporating personal or private information, such as social or economic data. The other caveat is that the data that is uploaded in the COTS IS is only available to users of the system, and unavailable to the public by default.

In general, there are solutions within the Power Platform to each of the constraints outlined above, but each progressive solution makes the overall implementation more complex, losing the benefits of simplicity that underpinned this choice of Power Platform for implementation. The implementation of the COTS IS as specified achieves the original design criteria established at the beginning of the project, however it would not be the recommended choice for a larger scale Information System designed to work across a larger range of collaborators and stakeholders, with granular file access requirements, or the need for more advanced APIs or a public-facing data portal.

This approach to the COTS IS was by design. The project brief was for a lightweight, effective build that could supercharge data sharing and facilitate innovation in the short term, with a plan to transition to one of the Information Systems being developed as part of the larger GBR Research Programs, the RRAP Modelling and Decision Support subprogram Information System or the RIMReP Data Management System, in the longer term. At all points the COTS IS was designed to align with developments in the RRAP M&DS IS and RIMReP DMS, and a transition plan for integration into the RRAP M&DS IS is outlined in section 5.5.

4.3 Outputs

CCIP-R-01 produced four key outputs:

- COTS Information System engagement to identify user data needs and workflows.
- Design of COTS Information System including metadata catalogue, data registry, data repository, process register, process repository, and provenance store.
- COTS Information System platform implemented in the Microsoft stack.
- Assessment of options and recommendations on transition to RIMReP or RRAP data and information systems, further discussed in Sections 5.4 and 5.5.

5. RESEARCH SYNERGIES AND NEXT STEPS

There are four core types of research synergies enabled by the COTS Information System: 1) data sharing and code reuse across CCIP projects and with COTS managers; 2) enabling reusable digital workflows; 3) digital delivery of science to Manager Dashboards at GBRMPA and the on-water decision support tool (CCIP-R-02, Fletcher et al. 2026); and 4) links to other GBR programs.

5.1 Links to other CCIP projects and data

The COTS Information System is designed to support three key functions in linking to other research projects across CCIP: 1) providing a federated output data storage and dissemination function, where only selected datasets are stored directly within the system while centralised metadata and registry entries link to relevant data stored elsewhere; 2) providing input data to models in other projects; and 3) delivering data from projects to managers via Power BI Dashboards or the COTS Control Centre on-water decision tool.

Projects across all three CCIP subprograms (i.e., detection, response and prediction) have provided or will provide data to be stored or registered in the COTS Information System, from field data from CCIP-P-05 (Benthic predation in rubble, Wolfe et al. 2025), to novel monitoring data including eDNA from CCIP-D-03 (Operationalising eDNA monitoring, Uthicke et al. 2025) and Scooter Assisted Large Area Diver based (SALAD) surveys from CCIP-P-04 (Pre-outbreak monitoring, Pratchett et al. 2025), to empirical outputs from CCIP-R-02 (Empirical decision support, Fletcher et al. 2026), and model outputs from CCIP-R-04 (Regional modelling, Skinner et al. 2025), CCIP-R-05 (COTS dispersal ensemble modelling, Choukroun et al. 2026), and CCIP-R-06 (Cost effectiveness of control, Scheufele et al. 2025).

Data from the COTS Control Program received into the COTS Information System via GBRMPA is processed by the Reusable Digital Workflows, expanded on in section 5.2 below, and made available to empirical workflows in CCIP-R-02 (Fletcher et al. 2026) and models in CCIP-R-03 (Reef-scale modelling, Rogers et al. 2025) and CCIP-R-04 (Regional modelling, Skinner et al. 2025).

Data and quantitative results from several CCIP projects are connected to managers via Power BI Dashboards, expanded on in section 5.3 below. These include data on eDNA from CCIP-D-03 (Uthicke et al. 2025) and SALAD surveys from CCIP-P-04 (Pratchett et al. 2025), empirical outputs from CCIP-R-02 (Fletcher et al. 2026), and model outputs from CCIP-R-04 (Skinner et al. 2025), CCIP-R-05 (Choukroun et al. 2026), and CCIP-R-06 (Scheufele et al. 2025).

5.2 Links to other CCIP projects – Reusable Digital Workflows

By design, there is a vital research synergy between the COTS Information System developed as part of CCIP-R-01 and the Reusable Digital Workflows developed as part of CCIP-R-02 (Fletcher et al. 2026). The Information System provides a central platform for storing, registering, and sharing data and processes, while the Reusable Digital Workflows define standardised, repeatable methods for transforming raw data into decision-ready outputs. Together, this combination is intended to allow data from the COTS Control Program and other research sources to be automatically processed and fed directly into decision-support tools and dashboards. This integration will enable operational efficiency but is also expected to enable faster, more transparent innovation by making it easier to test new ideas, reuse methods, and share insights across projects.

The most direct example is the preparation of cull and manta tow data from the COTS Control Program for distribution to researchers across CCIP. This is a process that was previously completed manually using a proprietary code base, but as the COTS Control Program and the volume of data it collected scaled up, this led to significant time lags between data collection and its availability for research. To resolve this, the data preparation workflow was implemented as a cutting-edge Reusable Digital Workflow, written in the open statistical language R. Once the Reusable Digital Workflow is directly integrated into the COTS Information System, it will be able to run automatically every time new COTS Control Program cull data is uploaded, to generate a real-time research dataset, along with the metadata and a link the provenance data required to use it within the COTS Information System. Moreover, the methods used to prepare research data are also accessible via the Processes component of the COTS Information System, allowing researchers to understand, reuse, and contribute to the code base, multiplying opportunities for innovation.

This approach, i.e., automated integration of the Reusable Digital Workflows into the COTS Information System to prepare and share data, will be useful in reducing manual work and speeding up data availability for research and decision support. While the current Information System is designed as a lightweight, short-to-medium term solution, this approach also demonstrates the potential for future digital innovation. In the longer term, similar methods could allow data to be automatically connected to networks of models and analysis pipelines, each processed automatically, with cutting-edge results delivered back to decision makers within hours instead of months.

5.3 Links to other CCIP research – Research Translation

The CCIP Research Translation activity aims to connect research outputs with management needs, ensuring that new knowledge is effectively integrated into operational decision-making. Another particularly important research synergy exists between the COTS Information System developed as part of CCIP-R-01, and the Manager Dashboards created as part of project CCIP-R-02 (Fletcher et al. 2026) and the CCIP Research Translation activity. The Manager Dashboards connect CCIP research outputs from multiple projects to the Power BI dashboards on computers used by COTS management staff at GBRMPA. Once the COTS IS is fully operational, dashboards will be able to pull data from the COTS Information System, which can then be interpreted and displayed by custom-designed Power BI dashboards. These dashboards have been developed by the CCIP Research Translation lead in close collaboration with managers to ensure the information required to inform effective decision making is displayed. Further information about the Power BI Dashboards developed as part of the COTS Information System is available in the companion CCIP Final

Technical Report for project CCIP-R-02, *Empirical Decision Support: using Control Program data to make real-world decisions* (Fletcher et al. 2026).

5.4 Links to other GBR Programs

By design, the COTS IS shares many similar components to the Information System being designed for the Reef Restoration and Adaptation Program Modelling and Decision Support Information System (RRAP M&DS IS) and the Reef Integrated Monitoring and Reporting Program Data Management System (RIMReP DMS). However, each system has been developed with distinct purposes and users in mind. The COTS IS was designed to address immediate, COTS-specific needs, focusing on linking research outputs directly to operational decision-making and supporting innovation across both management and research. In contrast, RRAP M&DS IS has primarily been developed as a modelling and decision support platform for researchers and modelers, without a current focus on operational management decision-making. Meanwhile, RIMReP DMS serves mainly as a federated data repository to support monitoring and reporting for managers and does not currently include advanced functionalities such as input data processing, provenance tracking, or integration with models and decision-support tools.

Each system has been designed to meet different needs and serves unique user communities — from operational managers to researchers and modelers. As such, any future integration should be driven by strategic alignment with program objectives, readiness of each system, access and governance requirements, and the ability to support both research innovation and practical management outcomes. This approach avoids premature technical commitments and ensures that future decisions are grounded in a thorough understanding of each system's capabilities, purpose, and operational context. The following section focuses on the key considerations that should guide future integration decisions

5.5 Next steps

While the short-term needs of a COTS Information System predicated the use of a rapidly developed, lightweight solution tailored for the most urgent COTS information needs, in the longer term, it will be strategically sensible to align the COTS Information System with larger Information Infrastructure efforts being developed on the GBR. These include the Information System being developed under the RRAP M&DS IS Subprogram, and the RIMReP DMS. This will be important both to minimise ongoing operational costs, but also because it is likely to unlock innovation dividends by pooling developments in data and processing techniques across many of the major ecological management questions on the GBR.

A full assessment of the relative strengths of the RRAP M&DS IS and the RIMReP DMS platforms as a final home for COTS information is beyond the scope of this report, but some preliminary insights can be summarised. As of 2024, the RRAP M&DS IS is in an active development phase, with early releases supporting internal modelling workflows and transitioning to a more generalised platform (Provena). Meanwhile, the RIMReP DMS has launched as an operational data access platform providing over 100 reef-related datasets, with ongoing improvements to expand coverage and interoperability. This evolving status is critical context when considering future integration and next steps.

Any potential future integration will require a system that can support both robust data storage and access, as well as the ability to track and manage processes and provenance information — key features needed to maintain transparency, reproducibility, and adaptive learning in COTS control and research. While the RRAP M&DS IS currently includes many of these necessary components, there is uncertainty around its long-term operational role and sustainability. Conversely, the RIMReP DMS, though primarily a federated data management platform today, could evolve to incorporate more advanced provenance and process-tracking capabilities in the future.

Rather than selecting a single preferred system now, we outline these functional requirements, intend to monitor the development trajectories of both systems, and engage collaboratively to determine the best long-term integration path for the COTS Information System. This balanced approach ensures flexibility and maximises alignment with broader reef data infrastructure strategies.

To facilitate the eventual transition from a short-term COTS-specific Information System to a longer-term solution as part of one of the larger data and information systems on the GBR, the COTS Information System has been designed to align with developments currently underway within both the RRAP M&DS IS and the RIMReP DMS. Specifically, the design uses similar components, specified in a similar manner, and structures the information collected in line with these other platforms, such as aligning metadata fields. These design choices mean that when the COTS IS is transitioned to one of these larger platforms, many components should be able to transition to the new infrastructure with minimal changes.

Implementing such a transition will require more detailed planning and depends on the maturity of data and management systems in RRAP and RIMReP, ability to access these systems, and time for the respective teams in those programs to facilitate the integration. An approximate estimate of the time required to manage this transition is between 12 to 15 months, depending on system readiness and the level of support from respective program teams.

A brief outline about how the COTS Information System architecture could be modified to integrate with the RRAP M&DS IS is presented below as an example. The proposed RRAP M&DS IS structure uses five of the six components defined for the existing COTS Information System: a Metadata Catalogue, Data Registry, Data Repository, Process Repository and Provenance Store. However, it implements these components using more advanced and scalable digital technologies. It is expected that the COTS IS Process Register component could be added to the RRAP M&DS IS using the same patterns that have been adopted to develop the Process Repository and the Data Registry, however how this could be implemented would have to be negotiated with the RRAP team.

Figure 17 shows a high-level view of the COTS Information System re-implemented on the RRAP M&DS IS platform. How the six components of the COTS Information System could be implemented in the RRAP M&DS IS is outlined below.

Metadata Catalogue: The Metadata Catalogue contains a collection of metadata about various datasets that are relevant to the COTS Control Program. This feature is implemented within RRAP M&DS IS using Amazon Web Services (AWS) storage and services. To store the metadata, the AWS Relational Database Service (RDS) is used, coupled with AWS Lambda to perform automated tasks. For more information around the Metadata Catalogue, refer to Section 3.1.

Data Registry: In the COTS Information System, the Data Registry contains a collection of descriptions for every dataset that is relevant to the COTS Control Program stored as a Microsoft List. This feature is implemented similarly in the RRAP M&DS IS, but it uses AWS storage and database services to provide a more scalable and extensible solution. While the datasets are stored within AWS S3, AWS DynamoDB is used to record descriptions, coupled with AWS Lambda to perform automated tasks.

Data Repository: In the COTS Information System, the Data Repository is implemented via Microsoft SharePoint. The data store feature in RRAP is a tailored solution using cloud services within AWS, providing significantly greater and more scalable storage capacity. It uses various storage and database services within AWS, such as AWS S3 for scalable storage of datasets, AWS DynamoDB for serverless storage of metadata and information about dataset descriptions, and AWS Lambda for automated serverless workflows. The data repository component utilises user authentication flows, mechanisms for registering metadata in the catalogue and data registry. These capabilities are likely to also be sufficient as currently implemented to address COTS Control Program requirements.

Process Register: The Process Register for COTS data processes will require additional extensions within the RRAP M&DS IS implementation. The Process Register is used to abstract the registration of a workflow or processing software from the storage of that software, to enable indexing and visibility of workflows and processes that are relevant to the COTS Control Program, but are owned and controlled by parties that have restrictions around sharing the information across other platforms for storage. The process register in the RRAP M&DS IS could be implemented using AWS RDS for storage of the structured data, where the data can be directly linked to the Process Repository (Component 5) or an external repository that is owned and controlled externally.

Process Repository: The Process Repository offers the modelling and decision teams access to established institutional or science community repositories to manage code for their simulation models. The COTS Information System has established a code repository infrastructure via Git, the current industry standard for managing code. The RRAP M&DS IS enables publications of links to repositories in two locations, the Provenance Registry and a Landing Portal that lists relevant code repositories, the latter of which can be used to link to CCIP Git repositories.

Provenance Store: The COTS IS Provenance Store uses a relatively simple structure to link input data and processes to the output data generated, based on Microsoft Lists. The Provenance Store and Registry within RRAP are implemented based on the extended vocabulary of PROV-O to suit the advanced specific needs of modelling and decision support in RRAP. The Registry allows registration of model run records, and other supporting registers to capture Activities, Entities and Agents. The Provenance Store features APIs, query capability and provenance graph visualisation of workflows and their related components (e.g., input data, output data, people, and organisations). Access to the Provenance Store and Registry is configured and may be restricted using token-based authentication. Because this represents a superset of the functionality required for the COTS Information System, it will easily encompass COTS Information System needs.

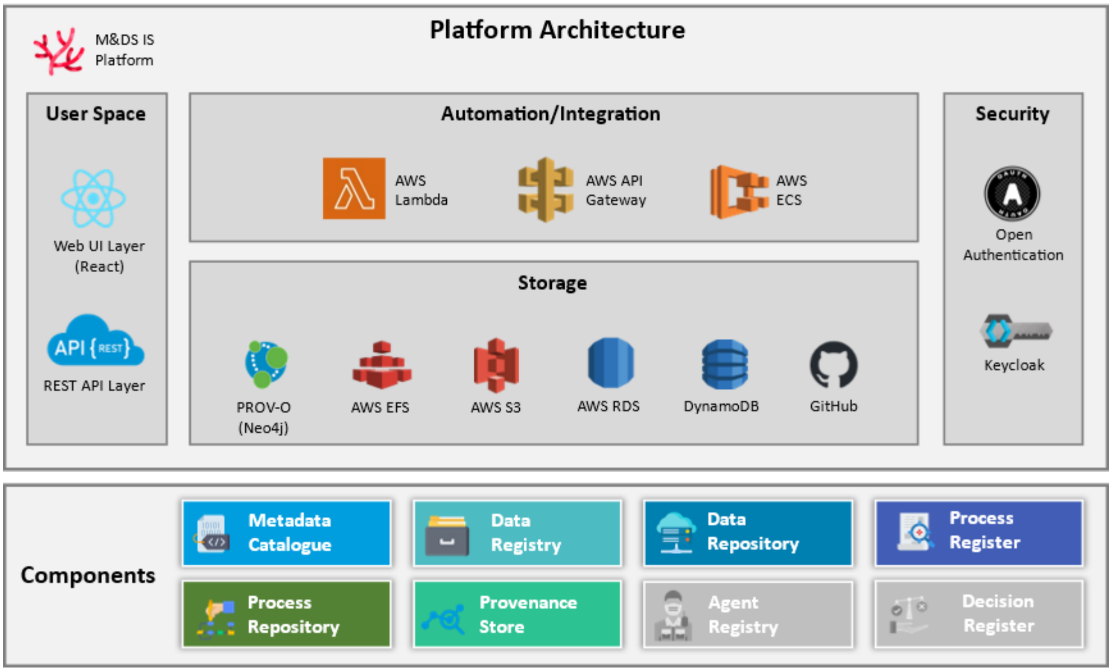


Figure 17. The set of components in a potential long-term solution that leverages the RRAP M&DS IS platform as a service.

6. MANAGEMENT IMPLICATIONS AND IMPACT

The COTS Information System provides vital connections between CCIP research across the Innovation Program and the management staff that use these research insights to drive real world change and innovation in the COTS Control Program. The COTS Control Program is supported by strong collaborations between managers, on-water operators, and researchers that allows it to leverage Control Program data to provide ecologically-informed decision support. However, this relies on many separate analysis, processing and interpretation workflows, each informing one or more decision-making processes. Once fully operational, the COTS Information System developed as part of CCIP-R-01 will provide a central platform to bring these workflows together to improve efficiency and enable research translation to amplify innovation.

The COTS Information System leverages modern data management capabilities to better facilitate informed decision-making in the COTS Control Program, by making data, and the ecological science used to analyse and interpret data for managers, more Findable, Accessible, Interoperable, and Reusable. The Information System is designed to connect management data to researchers and, once operational, to support automated processing through Reusable Digital Workflows. Together, this project (CCIP-R-01) and CCIP-R-02 (Fletcher et al. 2026) lay a foundation for the digital transformation of COTS research and management.

The key entry points for the project into COTS management are the On-water Operations and Data Collection and the Annual Reef Prioritisation Process. The project also connects to efforts in other GBR Research Programs such as RRAP and RIMReP. The connections include:

- **On-water Operations and Data Collection:** The COTS Information System is intended to streamline the flow of Control Program data, processed by the Reusable Digital Workflows from project CCIP-R-02 (Fletcher et al. 2026), to researchers, speeding up potential for innovation. It enables the flow of information to the manager-facing decision support tools developed by CCIP-R-02, including both the Manager Dashboards and the COTS Control Centre On-Water Decision Support System.
- **Annual Reef Prioritisation Process:** CCIP-R-01 delivers information to multiple Manager Dashboards that provide information that is used in the Annual Reef Prioritisation process. The Dashboards allow managers to dynamically interact with interpreted research results focused on the questions they need to answer. The Information System will allow new research results to be provided by researchers to automatically update the information provided to managers via the Manager Dashboards.
- **RRAP and RIMReP:** The COTS Information System is, intentionally, tightly integrated with similar efforts underway as part of the Modelling and Decision Support Subprogram of the RRAP and the Data Management System of RIMReP. The metadata standards used in the COTS IS align with those in the RIMReP DMS, and the architecture aligns with that used in the RRAP M&DS IS. These features will allow

the integration of the COTS Information System with these other information systems, unlocking innovation dividends by pooling developments in data and processing techniques across multiple GBR programs.

Project CCIP-R-01 contributed to the overarching outcomes and impacts identified in CCIPs Research Impact Plan and Program Logic (**Figure 1**). By developing a platform for improved data, research and knowledge sharing, it will deliver a more efficient and effective operational response, ensuring that data and research results can be shared between the Control Program and researchers quickly and reliably; that researchers can find and share intermediate results to amplify innovation, and that those results can be delivered back to decision makers at the times and places where decisions need to be made. The enabling innovations produced by CCIP-R-01 will allow other research efforts innovating detection and monitoring to be integrated into research and decision making more effectively and will help those improved data flow back to managers to inform more effective decisions. By reducing the barriers to information flow across research and management, it drives impacts across all three areas identified in the CCIP Program Logic: better suppression and prevention of COTS outbreaks, protection of coral cover, leading to benefits for Traditional Owners, the tourism industry, and the Australian community as a whole.

7. ACKNOWLEDGEMENTS

We acknowledge the Traditional Owners of the Great Barrier Reef and its catchments. We also thank researchers from across CCIP, COTS Control Program management staff from GBRMPA, and staff from on-water operators implementing COTS Control who contributed to user workshops that improved the design of the COTS Information System.

8. DATA ACCESSIBILITY

Outputs from many projects across CCIP will be registered and catalogued in the COTS Information System, making them findable and accessible to collaborators involved in CCIP through their organisational credentials. While certain key datasets may be stored directly within the system (for example, summary products or smaller processed files), most project data will remain in institutional or external repositories, with links and metadata maintained in the COTS IS to enable a federated access approach. Interpreted and visualised versions of some of these outputs will be available on Power BI Dashboards within GBRMPA. Some processes will be available on GitHub, linked from within the COTS Information System.

9. REFERENCES

Bozec YM, Hock K, Mason RA, Baird ME, Castro-Sanguino C, Condie SA, Puotinen M, Thompson A, Mumby, PJ (2022) Cumulative impacts across Australia's Great Barrier Reef: A mechanistic evaluation. *Ecological Monographs*, *92*(1), p.e01494. https://doi.org/10.1002%2Fecm.1494

Choukroun S, Bode M, Stewart O, Porobic J, Langlais C, Lambrechts J, Mason L (2026) Crown-of-thorns starfish (COTS) connectivity modelling under multidimensional uncertainties on Australia's Great Barrier Reef. A report to the Australian Government by the COTS Control Innovation Program

Claar DC, Szostek L, McDevitt-Irwin JM, Schanze JJ, Baum JK (2018) Global patterns and impacts of El Niño events on coral reefs: A meta-analysis. *PLOS ONE* 13:e0190957. https://doi.org/10.1371/journal.pone.0190957

De'ath G, Fabricius KE, Sweatman H, Puotinen M (2012) The 27-year decline of coral cover on the Great Barrier Reef and its causes. *Proceedings of the National Academy of Sciences* 109:17995-17999. https://doi.org/10.1073/pnas.1208909109

Fletcher CS, Bonin MC, Westcott DA (2020) An ecologically-based operational strategy for COTS Control: Integrated decision making from the site to the regional scale. Reef and Rainforest Research Centre Limited, Cairns (65pp). NESP-TWQ-Project-3.1.1-Technical-Report-2.pdf

Fletcher CS, Bonin MC, Caballes CF, Gómez-Cabrera MC, Kroon FJ, Mankad A, Pratchett MS, Uthicke S, Westcott DA (2021) Design of the COTS Control Innovation Program: a technical report and recommendations. A report to the Australian Government by the COTS Control Innovation Program (149pp). CCIP-Design-Phase-Technical-Report.pdf

Fletcher CS, Chen C, Waters EK, Matthews S, Rezvani M, Lawrence E (2026) Empirical decision support: Using crown-of-thorns starfish (COTS) Control Program data to make real-world decisions. A report to the Australian Government by the COTS Control Innovation Program

Gardner TA, Côté IM, Gill JA, Grant A, Watkinson AR (2003) Long-Term Region-Wide Declines in Caribbean Corals. *Science* 301:958-960. https://doi.org/10.1126/science.1086050

GBRMPA (2020) Integrated pest management operations manual for crown-of-thorns starfish control program vessels. Great Barrier Reef Marine Park Authority, Townsville

GBRPMA (2017) Great Barrier Reef blueprint for resilience. Great Barrier Reef Marine Park Authority, Townsville. https://hdl.handle.net/11017/3287

Hoegh-Guldberg O (1999) Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research* 50:839. DOI:10.1071/MF99078

Hughes TP, Kerry JT, Simpson T (2018) Large-scale bleaching of corals on the Great Barrier Reef. *Ecology* 99:501-501. https://doi.org/10.1002/ecy.2092

Matthews SA, Williamson DH, Beeden R, Emslie MJ, Abom RTM, Beard D, Bonin M, Bray P, Campili AR, Ceccarelli DM, Fernandes L, Fletcher CS, Godoy D, Hemingson CR, Jonker MJ, Lang BJ, Morris S, Mosquera E, Phillips GL, Sinclair-Taylor TH, Taylor S, Tracey D, Wilmes JC, Quincey R (2024) Protecting Great Barrier Reef resilience through effective management of crown-of-thorns starfish outbreaks. *PLOS ONE* 19:e0298073. https://doi.org/10.1371/journal.pone.0298073

Mellin C, Matthews S, Anthony KR, Brown SC, Caley MJ, Johns KA, Osborne K, Puotinen M, Thompson A, Wolff NH, Fordham DA, Macneil A (2019) Spatial resilience of the Great Barrier Reef under cumulative disturbance impacts. *Global Change Biology*, *25*(7), pp.2431-2445. DOI:10.1111/gcb.14625

Pratchett MS, Caballes CF, Rivera-Posada JA, Sweatman HPA (2014) Limits to Understanding and Managing Outbreaks of Crown-of-Thorns Starfish (*Acanthaster* spp.). *Oceanography and Marine Biology: An Annual Review* 52:133-200. DOI:10.1201/b17143-4

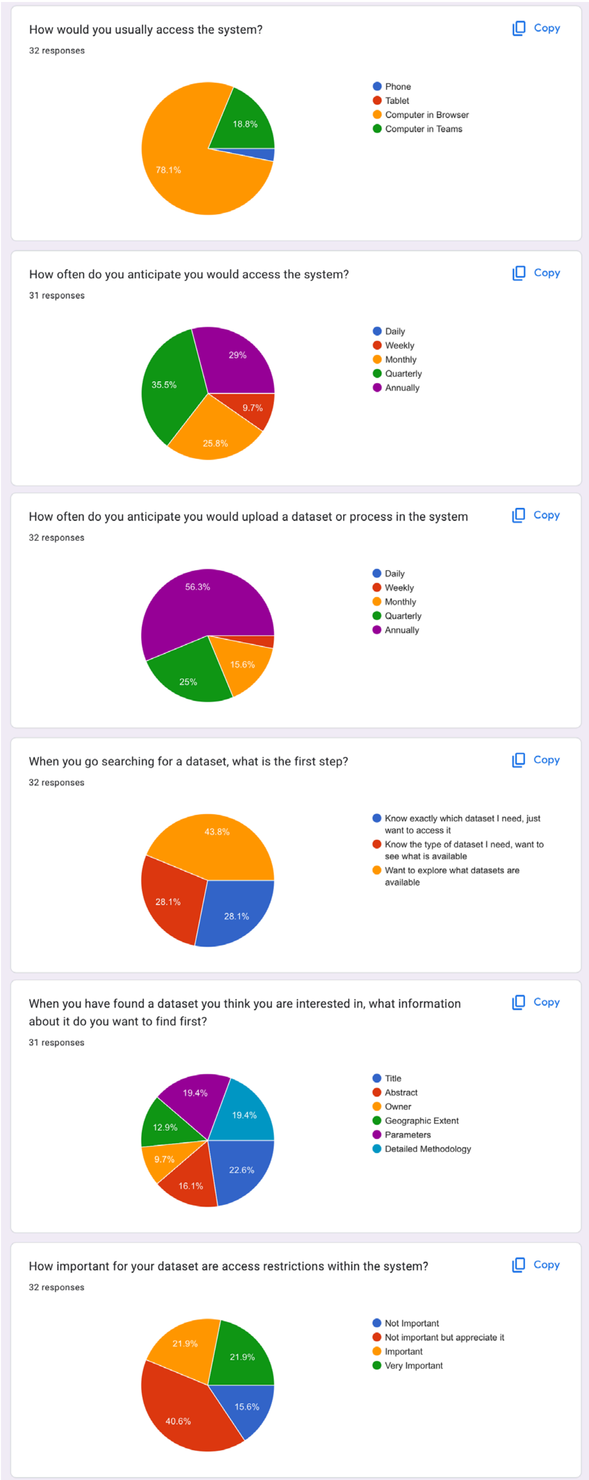
Pratchett MS, Doll PC, Chandler JF, Doyle JR, Uthicke S, Dubuc A, Caballes CF (2025) Early detection of renewed population irruptions of Pacific crown-of-thorns starfish (*Acanthaster* cf. *solaris*, COTS) on Australia's Great Barrier Reef. A report to the Australian Government by the COTS Control Innovation Program (53 pp) CCIP-P-04-Final-Report-SALAD-Surveys.pdf

Scheufele G, Skinner CS, Fletcher C (2025) Economic assessment of manual crown-of-thorns starfish (COTS) control scenarios on the Great Barrier Reef. A report to the Australian Government by the COTS Control Innovation Program (70 pp). CCIP-R-06-Final-Report-COTS-Control-Economic-Assessment.pdf

Skinner C, Condie SA, Fletcher CS, Mumby PJ (2025) Assessing alternative control scenarios for crown-of-thorns starfish (COTS) on the Great Barrier Reef: An ensemble approach. A report to the Australian Government by the COTS Control Innovation Program (61 pp) CCIP-R-04-Final-Report-Regional-Modelling.pdf
Uthicke S, Gomez Cabrera M, Patel F, Lawerence E, Tabor B, Foster S, Doyle J (2025) Operationalising and implementing crown-of-thorns starfish (COTS) eDNA monitoring on the Great Barrier Reef. A report to the Australian Government by the COTS Control Innovation Program (97 pp). CCIP-D-03-Final-Report-eDNA-Monitoring.pdf
Westcott D, Fletcher C, Kroon F, Babcock R, Plaganyi-Lloyd E, Pratchett M, Bonin M (2020) Relative efficacy of three approaches to mitigate Crown-of-Thorns Starfish outbreaks on Australia's Great Barrier Reef. *Scientific Reports* 10:12. https://doi.org/10.1038/s41598-020-69466-1
Wilkinson MD, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, Blomberg N, Boiten J-W, da Silva Santos LB, Bourne PE, Bouwman J, Brookes AJ, Clark T, Crosas M, Dillo I, Dumon O, Edmunds S, Evelo CT, Finkers R, Gonzalez-Beltran A, Gray AJG, Groth P, Goble C, Grethe JS, Heringa J, 't Hoen PAC, Hooft R, Kuhn T, Kok R, Kok J, Lusher SJ, Martone ME, Mons A, Packer AL, Persson B, Rocca-Serra P, Roos M, van Schaik R, Sansone S-A, Schultes E, Sengstag T, Slater T, Strawn G, Swertz MA, Thompson M, van der Lei J, van Mulligen E, Velterop J, Waagmeester A, Wittenburg P, Wolstencroft K, Zhao J, Mons B (2016) The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data* 3:160018. https://doi.org/10.1038/sdata.2016.18
Wolfe K, Desbiens AA, Uthicke S, Patel F, Dworjanyn S, Riginos C, Byrne I, Fisher E, Mumby PJ (2025) Resolving the impact of benthic and cryptic predation on crown-of-thorns starfish (COTS). A report to the Australian Government by the COTS Control Innovation Program (73 pp). CCIP-P-05-Final-Report.pdf

APPENDIX A – USER ENGAGEMENT SURVEY RESULTS

The result of the user engagement survey on using the COTS Information System is as follows:



Cameron S. Fletcher
e: cameron.fletcher@csiro.au
m: 0488 413 845

COTS Control Innovation Program | A research and development partnership to better predict, detect and respond to crown-of-thorns starfish outbreaks