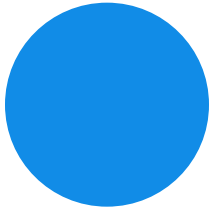


Critical Knowledge Index

Identification and Prioritization of **Critical** Knowledge

December, 2015

Columbia University and NASA

INFORMATION AND KNOWLEDGE STRATEGY

Master of Science

COLUMBIA UNIVERSITY
School of Professional Studies

The IKNS Capstone Project

Class of 2015: 55 Students
18 Sponsors

Consulting project to initiate or improve information and knowledge processes, or to expand revenue opportunities from intelligent, knowledge-enabled products.

The IKNS-NASA Capstone Team

Goal

Recommend a method for implementing a continuous and formal effort to **Identify**, **Prioritize**, **Capture** and **Transfer** critical knowledge.

- ✓ Ensure knowledge, that is at the risk of being lost, is preserved.
- ✓ Expand the Agency's intellectual capital across NASA's enterprises and generations.
- ✓ Support the NASA workforce in successfully carrying out NASA's missions.

Michael Bell, Ph.D.

Rohit Bhatia

Columbia IKNS '15
Corning Incorporated

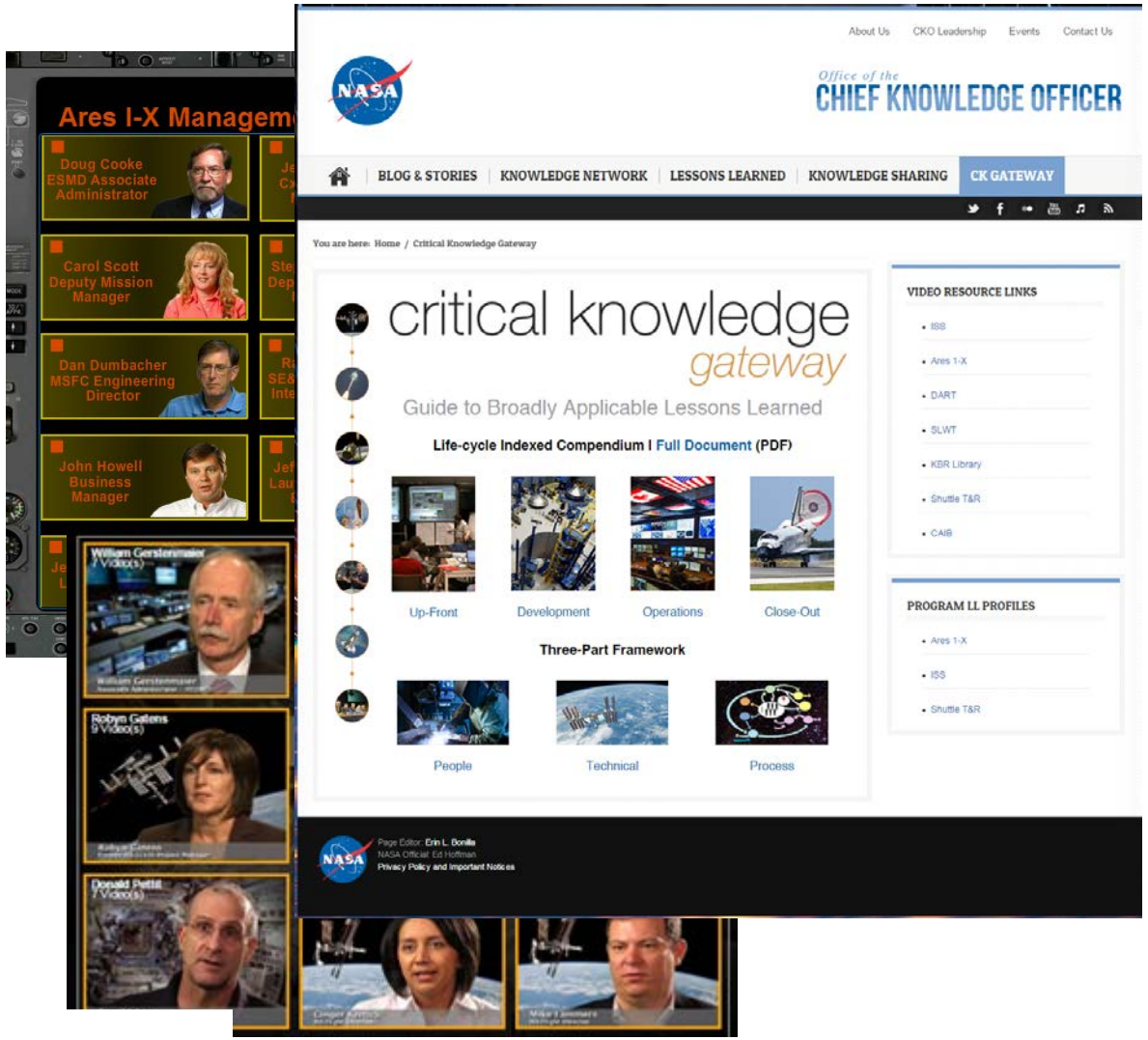
Ronald Realubit

Columbia IKNS '15,
Columbia Genome Center

Erika Vargas

Columbia IKNS '15, The World Bank

NASA **Critical** Knowledge Initiative (January 2015)



"Critical Knowledge is defined as broadly applicable lessons learned that *enable mission success*, *stimulate critical thinking* and *help raise questions* that need to be addressed at various phases in a project life-cycle."

Critical Knowledge Gateway Compendium

Two-part classification approach:

1.) A notional simplified project timeline
- Up-Front
- Development
- Operations
- Close-out

2.) High-level topical themes
- People
- Technical
- Process

NASA **Critical** Knowledge Referee Process (June 2015)

Knowledge Referees determine which lessons:

- Possess *broad applicability*
- Involve ***Top 5%*** of updateable knowledge most important for programmatic & engineering missions to learn
- Involve knowledge that *keeps evolving* towards new applications and missions
- Lends itself to a *formal process* as candidates for formal *incorporation into appropriate policies and technical standards as well as to technical workforce development products and activities to prevent skills dissipating over time*

NASA Knowledge Community

- Incorporate and integrate dispositions into agency digital tools and across CKOs

Agency CKO and Knowledge Referees

- Validate priorities
- Coordinate disposition recommendations
- Identify current and new agency activities and resources to address recommended dispositions

NASA **Critical** Knowledge Referee Process (June 2015)

Knowledge Referees

People
[OHCM] Office of Human Capital Management

Process
[OSMA] Office of Safety and Mission Assurance

Discipline Technical
[NESC] NASA Engineering & Safety Center

Knowledge Transfer & Digital Technology (Services)
Agency CKO

Disposition Activities

- Training/Development
- Knowledge Service
- HCM
- Policy & Procedure
- Process
- Awareness
- Other

Agency Digital Tools

- Search
- Analytical/Visualization Tools
- Collaboration Platforms

Top 3 priorities identified in each NASA **Critical** Knowledge Element

People

1. Address Toxic Management
2. Improve communications at all organizational levels
3. Improve situated and virtual teamwork

Process

1. Improve Risk-Informed decision-making
2. Improve requirements definition process
3. Improve agile versus rigor procedures and hybrids

Knowledge Transfer & Digital Technology

1. Identification and integration of Agency sources for improved findability and searchability
2. Formalization of lessons-learned process
3. Increased executive participation

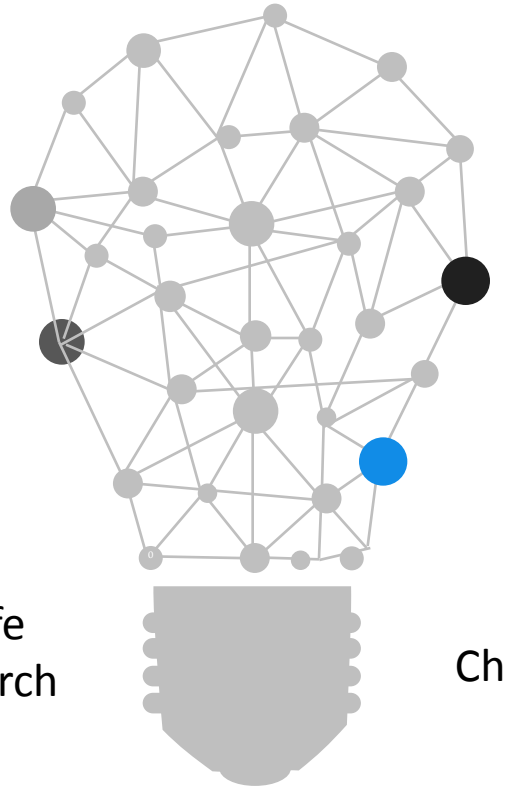
Technical Discipline

1. Improve technical perspective on cost versus requirements trade capability
2. Address decision biases when working technical problems
3. Implement iterative capability to refresh technical knowledge

Critical Knowledge Benchmarking

THE WORLD BANK
IBRD • IDA

International Development



European Space Agency

esa

CORNING
Discovering Beyond Imagination

Glass & Ceramic Product Manufacturing

Russian Federal Space Agency

POCKOCMOC

COLUMBIA SYSTEMS BIOLOGY

Academic Life Science Research

China National Space Administration

CNSA

A continuous and formal method for Identifying, Prioritizing, Capturing and Transferring Critical Knowledge is largely a novel concept.

IKNS-NASA Capstone Project: Two Main Dimensions

First (I) Dimension

Define, Identify and Prioritize Critical Knowledge

Lessons Learned +

Critical Thinking +

Critical Knowledge Index (CKI) =

Critical Knowledge (Top 5%)

Second (II) Dimension

Capture and Transfer Critical Knowledge

Critical Knowledge + Knowledge Service implementation into policies and formal standards

IKNS Critical Knowledge Framework

Critical Knowledge Index

Steps to Identify and Prioritize **Critical** Knowledge

Lessons Learned Entries from Kennedy Space Center

1. **Knowledge Classification**
   Classify knowledge based on 3 categories
2. **Critical Knowledge Framework**
   Apply 0-5 scoring system to 5 knowledge criteria
3. **Critical Knowledge Index (CKI)**
   Calculate CKI based on a formula.
4. **CKI Ranking & Prioritization**
   Top 5% most relevant items to constitute agency wide CK
5. **Trends and Decision Making**
   CKI dashboard

Critical Knowledge Classification Categories

Category 1
Project Life-Cycle

UP-FRONT
Architecture studies, Forming the project team, defining roles & responsibilities, systems requirements definition, earliest milestones

DEVELOPMENT
From PDR onward through CDR and into manufacturing phases

OPERATIONS
Ground processing, launch, and on-orbit operations of a space system.

CLOSE-OUT
Deorbit, program/project termination, facility closure, human resource management, close out of records, historical recordation, environmental cleanup

Category 2
Project Element

PEOPLE
Factors Involving:
- Communications
- Individual Behavior
- Team Behavior
- Organizational Culture
- Expectations

DISCIPLINE TECHNICAL
Content and Lessons related to specific domains of practice

PROCESS
Factors addressing specific actions towards defined outcomes in a system perspective.

KNOWLEDGE TRANSFER & DIGITAL TECHNOLOGY
Factors involving moving knowledge across organizational boundaries and digital information and communications tools that enable and accelerate interaction and learning.

Category 3
Knowledge Services Area

INFORMATION MANAGEMENT
Databases, Codification practices, Findability, Access, Knowledge technologies

COLLABORA-TION / NETWORK
Social capital, Tacit to Explicit, Working environment, Network dynamics, Network design

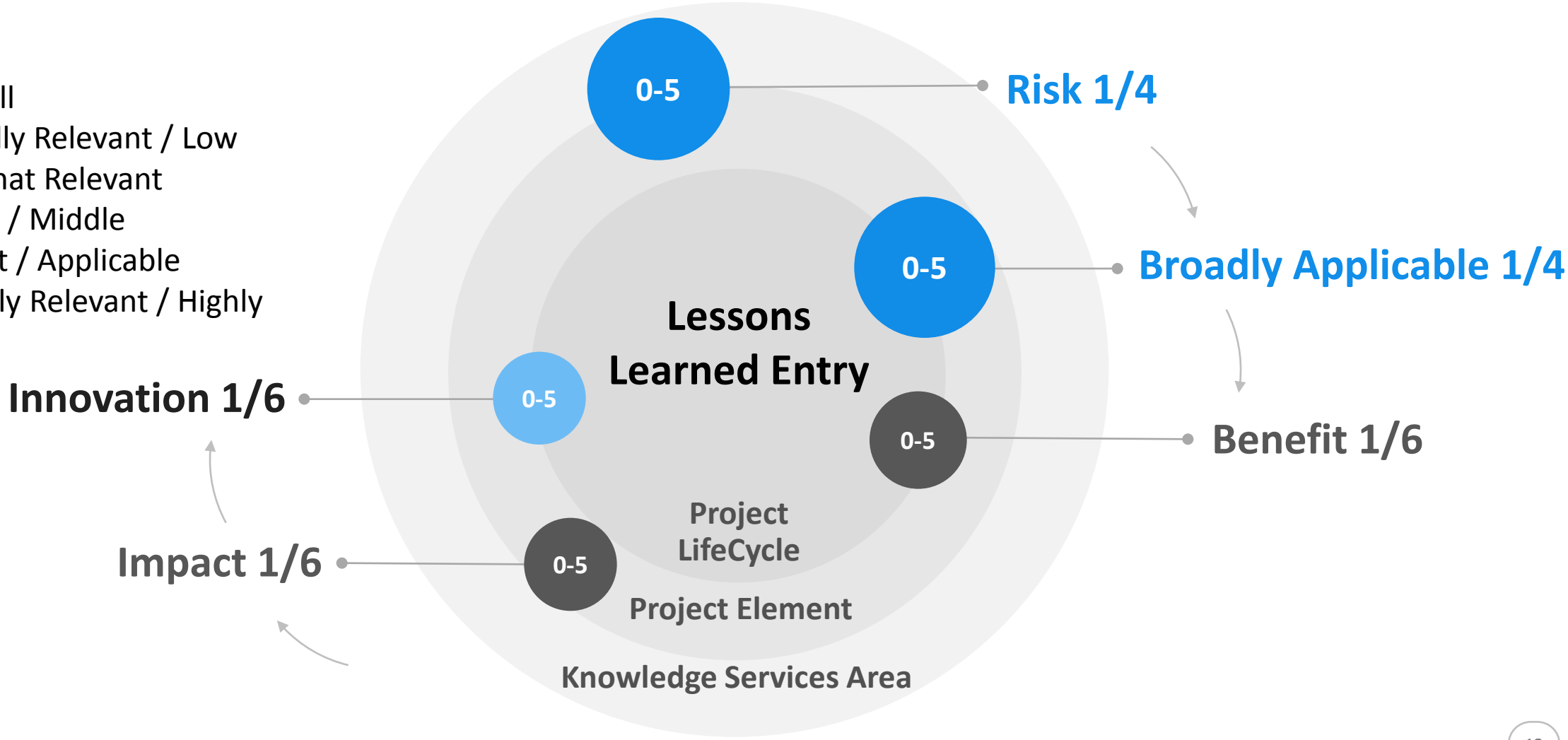
PROJECT MANAGEMENT
Scope, Resource allocation, Planning, SMART goals

GOVERNANCE
communicated Vision, Leadership, Common Goals, Acknowledgement, short-term wins

Critical Knowledge: Lessons Learned Scoring System

Scoring System on a scale from 0-5 where:

0 - Not at all
1 - Minimally Relevant / Low
2 - Somewhat Relevant
3 - Average / Middle
4 - Relevant / Applicable
5 - Definitely Relevant / Highly applicable



The Critical Knowledge Index - CKI

Calculated from the scores in the Critical Knowledge Framework

CK Framework Variables can have different weights in the formula

Risk (R) = 1/4

Broadly Applicable (BA) =1/4

Impact (I) = 1/6

Benefit (B) = 1/6

Innovation (In) = 1/6

Formula:

CKI = [1/4• R] + [1/4 • BA] + [1/6• I] + [1/6 • B] + [1/6 • In]

Critical Knowledge Index Variables

Risk (R)

Situation, process or behavior involving some exposure to danger (e.g. High Risk vs. Low Risk)

Broadly Applicable (BA)

Extent to which knowledge can be deployed in diverse contexts across the agency (e.g. Marginally applicable vs. Broadly applicable)

Impact (I)

Knowledge that has a substantial effect on enhancing project outcomes (e.g. Low Impact vs. High Impact)

Benefit (B)

Comparative advantage gained from something (e.g. Marginal Benefit vs. Substantial Benefit)

Innovation (In)

Viewed as the application of better solutions emanating from new knowledge that meet evolving requirements (e.g. Blind Spot vs. New Insight)

Lessons Learned Scoring Survey Examples

Knowledge ID	Subject	Knowledge (KSC Lessons Learned)	Project Life Cycle	Project Element	Knowledge Service Area	Risk	Broadly Applicable	Impact	Benefit	Innovation	CKI
12901	Procurement of Nonconforming Titanium Alloys	As counterfeiting of aerospace parts and materials has become increasingly commonplace, flight system and instrument developers must exercise a high level of vigilance and institute screening processes that are sufficiently rigorous to counter the risk.	Operations	Discipline Technical	Project Management	5	5	5	5	3	4.67
11501	Mars Science Laboratory Actuator Design Process Escape	Demand a higher standard of proof-of-readiness prior to incorporation of risky new technology. This proof did not exist at the time the MSL project chose to implement titanium gearing (for mass reduction) and dry lubricant gear coating (for cryogenic operation without active heating).	Up-Front	Process	Project Management	4	5	4	5	5	4.58
12901	Procurement of Nonconforming Titanium Alloys	Assure that a thorough review of all Certification Data Packages accompanying received Ti alloys is performed by trained and experienced Materials & Processes (M&P) engineers, Procurement Quality Assurance (PQA) specialists, or equivalent personnel.	Up-Front	People, Process	Project Management	4	5	5	5	3	4.42
12901	Procurement of Nonconforming Titanium Alloys	Material suppliers should be Nadcap (National Aerospace and Defense Contractors Accreditation Program) certified, and they should be audited and approved by PQA and M&P engineers and placed on an Approved Suppliers List (ASL).	Up-Front	Process	Project Management	4	5	5	5	3	4.42
12901	Procurement of Nonconforming Titanium Alloys	All procurements should require that the material type and specifications be listed in the contract.	Up-Front	Process	Project Management	4	5	5	5	3	4.42
12901	Procurement of Nonconforming Titanium Alloys	Material testing should be performed on a sample basis to validate the supplier's material test reports.	Development	Process	Change Management	4	5	5	5	3	4.42
5006	Evolution and Management of Spacecraft Configuration	The effects of baseline changes on budgets need to be understood before new baselines are accepted.	Development	Process	Project Management	4	4	3	3	1	3.17
6358	Thermal Environments Data File Format	It is preferable to use a simple, easy to read and understand file format so that it can be reviewed in any text viewer. Also its contents can easily be plotted.	Up Front	Process	Information Management	1.5	2.5	2	3	1	2

Operationalization of the CKI as a Decision Making tool

There are two ways in which the CKI could be used:

1. Formulate a threshold value and then classify any lessons learned with a CKI above that value as part of the agency's CK.

2. Rank lessons learned and choose a certain fraction (5%) with the highest CKI scores to constitute the agency's CK.

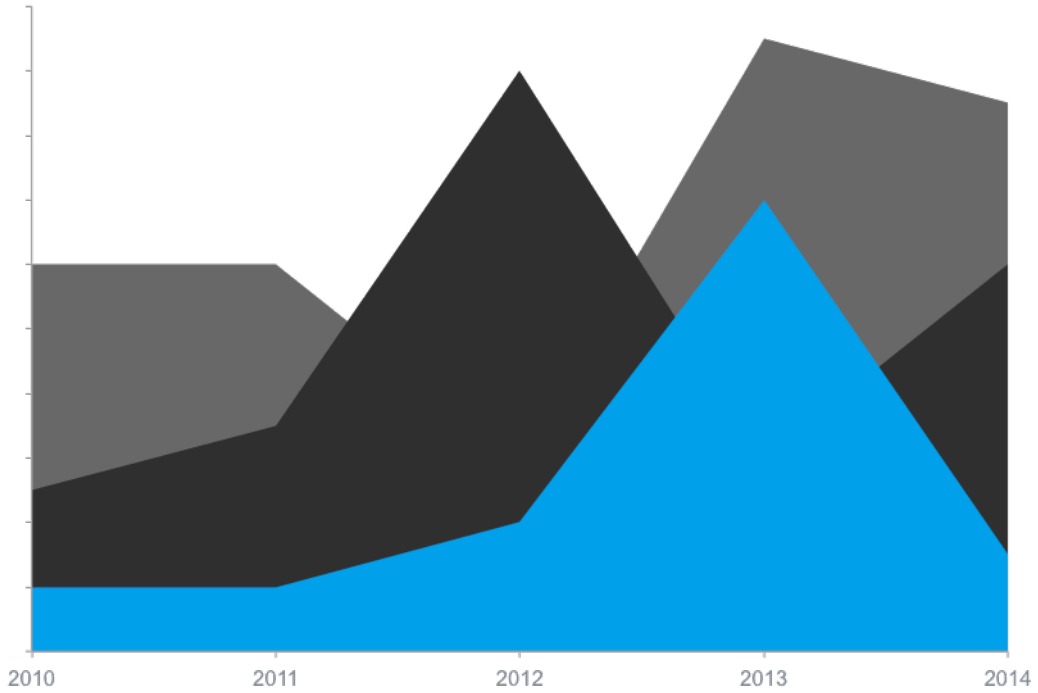
On the basis of the criteria set by NASA, it was decided that the lessons learned with the Top 5% CKI values would conform the agency's CK.

CKI Visualization Dashboard: Exploring **Identified** and **Prioritized** Critical Knowledge

Apply CK Framework
Classification Categories

CKI Ranking:
List of top 5% lessons learned

Browse Top 5% Entries
for each category combination



Project Life-Cycle
- Up-Front
- Operations
- Development
- Close-Out

Project Element
- People
- Knowledge Transfer & Digital Technology
- Process
- Discipline Technical

Knowledge Services Area
- Infor. Mgmt.
- Project Mgmt.
- Collaboration
- Governance

Questions

- Should the CKI also take into account the experience and position of the user applying the scores in the CK Framework?
- How should the age of the knowledge or date it was recorded influence its effect on the CKI?
- What is the natural extension of the CKI to prioritize other knowledge products generated by NASA?

Further Considerations

- Classification filters allow to focus CK framework implementation.
- Methodology can be customized with different variables and weights in CKI formula.
- Selection criteria (e.g. currently top 5% CKI) can be tailored to adjust CK flow appropriately to account for limited bandwidth.