EXPLORATION CLINICAL DECISION SUPPORT SYSTEM

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ABSTRACT

The Exploration Clinical Decision Support (ECDS) System project is intended to enhance the Exploration Medical Capability (ExMC) Element for extended duration, deep-space mission planning in HRP. A major development guideline is the Risk of "Adverse Health Outcomes & Decrements in Performance due to Limitations of In-flight Medical Conditions". ECDS attempts to mitigate that Risk by providing crew-specific health information, actionable insight, crew guidance and advice based on computational algorithmic analysis. The availability of inflight health diagnostic computational methods has been identified as an essential capability for human exploration missions. Inflight electronic health data sources are often heterogeneous, and thus may be isolated or not examined as an aggregate whole. The ECDS System objective provides both a data architecture that collects and manages disparate health data, and an active knowledge system that analyzes health evidence to deliver case-specific advice. A single, cohesive space-ready decision support capability that considers all exploration clinical measurements is not commercially available at present. Hence, this Task is a newly coordinated development effort by which ECDS and its supporting data infrastructure will demonstrate the feasibility of intelligent data mining and predictive modelling as a biomedical diagnostic support mechanism on manned exploration missions.

The initial step towards ground and flight demonstrations has been the research and development of both image and clinical text-based computer-aided patient diagnosis. Human anatomical images displaying abnormal/pathological features have been annotated using controlled terminology templates, marked-up, and then stored in compliance with the AIM standard. These images have been filtered and disease characterized based on machine learning of semantic and quantitative feature vectors. The next phase will evaluate disease treatment response via quantitative linear dimension biomarkers that enable image content-based retrieval and criteria assessment. In addition, a data mining engine (DME) is applied to cross-sectional adult surveys for predicting occurrence of renal calculi, ranked by statistical significance of demographics and specific food ingestion. In addition to this precursor space flight algorithm training, the DME will utilize a feature-engineering capability for unstructured clinical text classification health discovery. The ECDS backbone is a proposed multi-tier modular architecture providing data messaging protocols, storage, management and real-time patient data access. Technology demonstrations and success metrics will be finalized in FY16.

Exploration Clinical Decision Support System: Medical Data Architecture

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Medical Data Architecture Overview

- Background
  - ExMC Risk Statement and Gap
  - ECDS Medical System Goal
- FY16 Data Architecture
  - High Level Elements & Layers
  - Implementation & Iterative Release
- Development Roadmap
- EMSD Lessons Learned & Summary

ExMC Risk Statement and Mitigation

Given that medical conditions will occur during human spaceflight missions, there is a possibility of adverse health outcomes & decrements in performance during these missions and for long term health.

- *A medical support system will be developed with a data architecture to optimize crew ability to perform semi-autonomous and autonomous medical care as needed during exploration class missions.*
- *The tasks will include concept, policy and engineering development, applied research, prototype creation as well as systems design.*
- *Early proof-of-concept is emphasized to validate and update approaches to the medical support system.*

Exploration Medical Capability (ExMC) Risk and Gap

Risk –

Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions

Gap Med 7:

We do not have the capability to comprehensively process medically-relevant information to support medical operations during exploration missions.

Gap Med 10:

We do not have the capability to provide computed medical decision support during exploration missions.

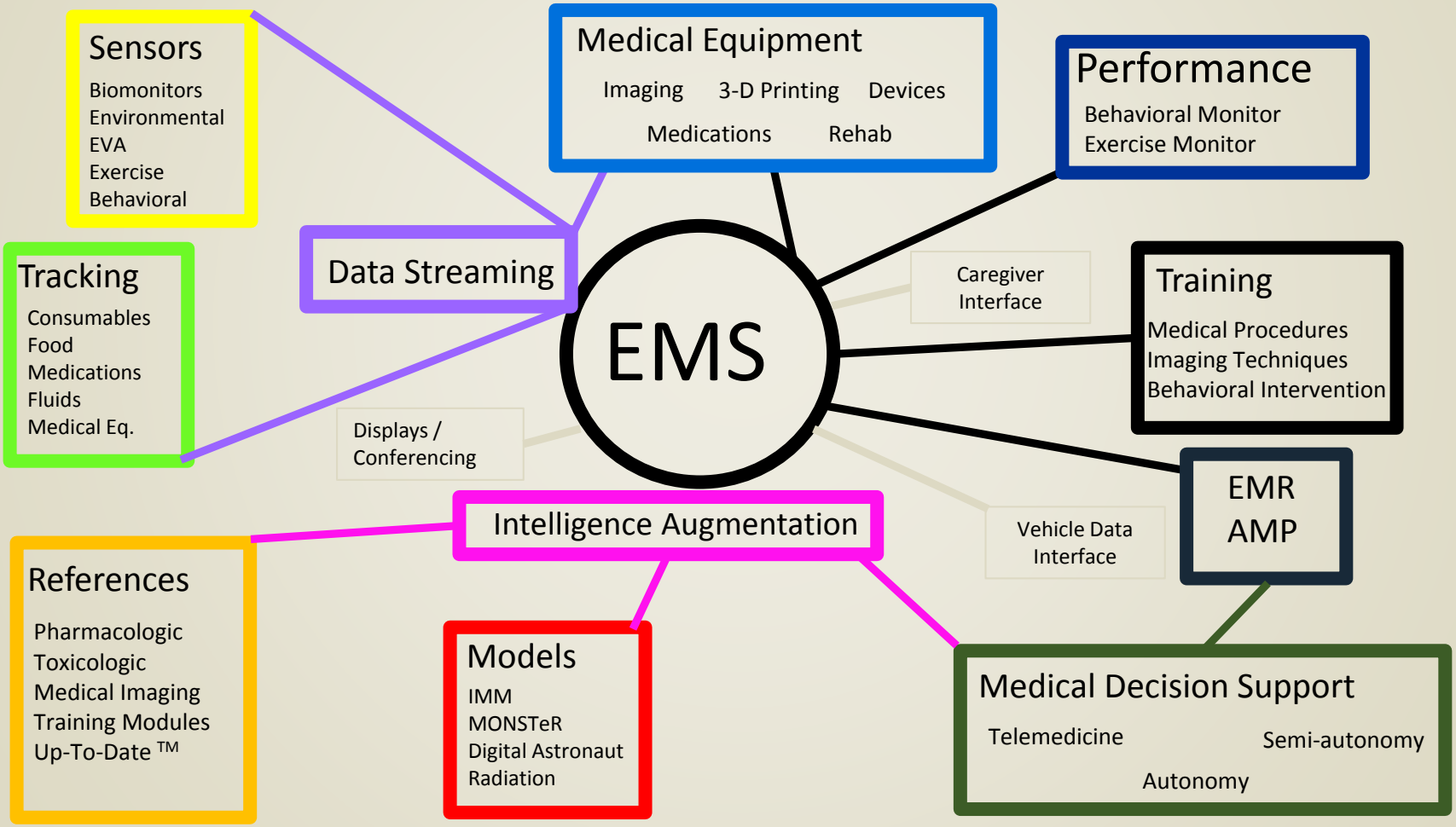
Research Approach for ECDS:

Develop the capability to collect, store, mine, model and transform contextual data into actionable knowledge.

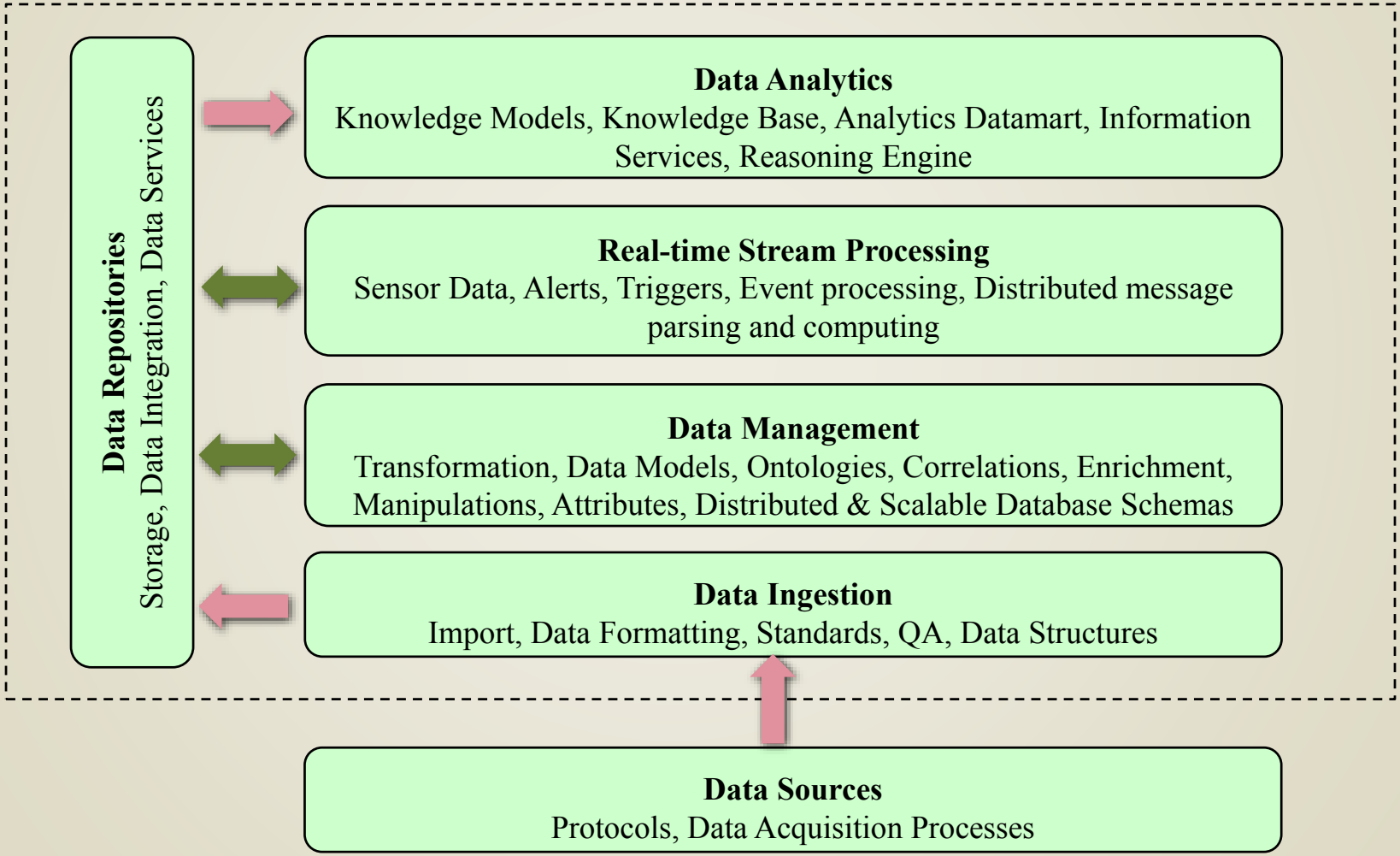
Exploration Medical System Goal

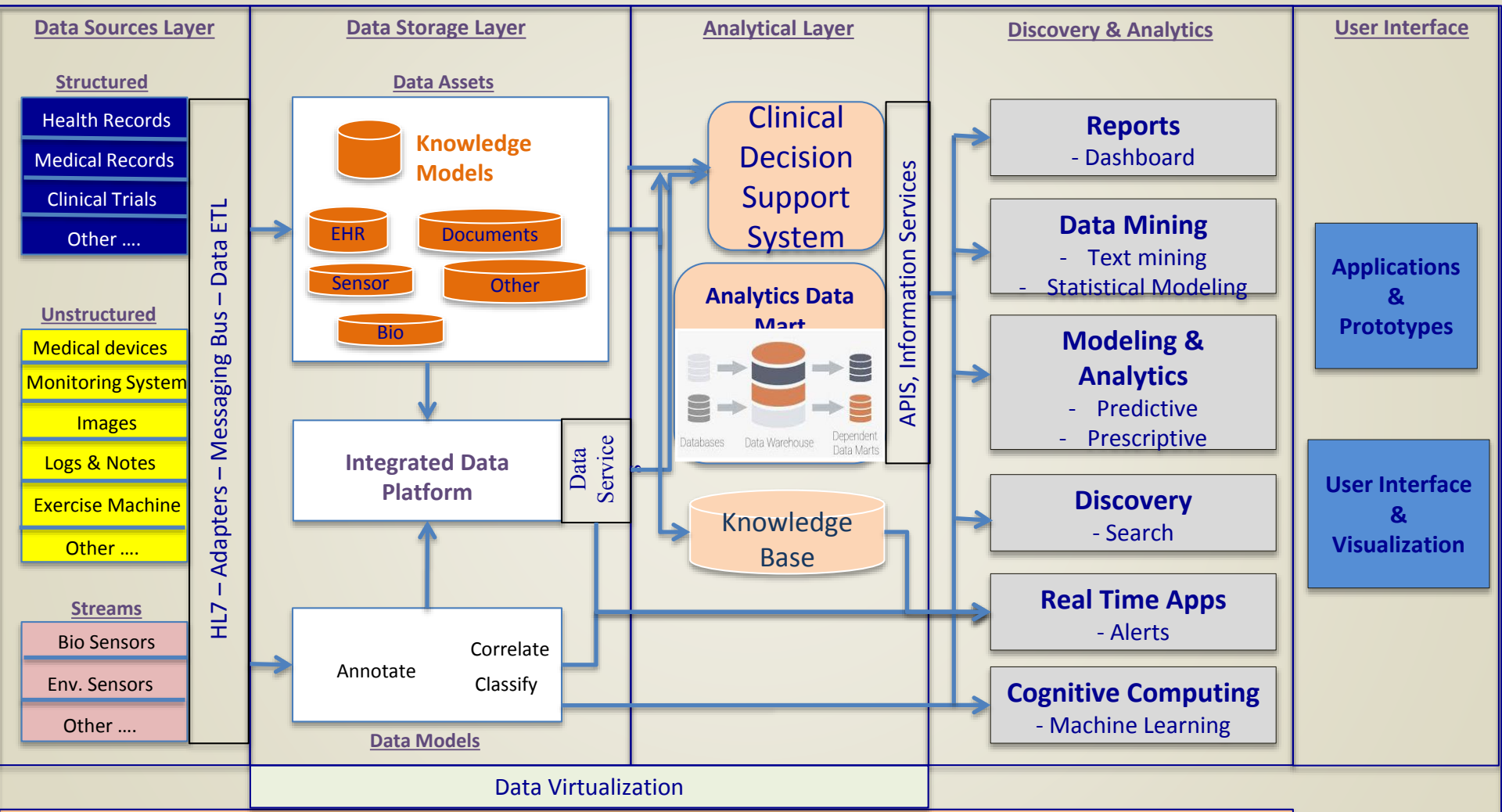
- A comprehensive medical system to support the crew in Exploration Missions targeting autonomy.
- In order to do this, ExMC requires integration with vehicle systems – single point solutions are not desirable for Exploration Missions.
- *Networked Exploration Medical Information Support and Integration System*
  - *Provide for centralized medical care*
  - *Enhance available knowledge base*
  - *Provide for electronic training needs*
  - *Monitor supplies for crew*
  - *Monitor crew as needed*
  - *Streamline communication with ground flight surgeons*
  - *Decrease likelihood of medical errors*

Medical System Capture Diagram



High Level Architecture Elements




Data Sources Layer
Structured
Health Records
Medical Records
Clinical Trials
Other ....
Unstructured
Medical devices
Monitoring System
Images
Logs & Notes
Exercise Machine
Other ....
Streams
Bio Sensors
Env. Sensors
Other ....
HL7 – Adapters – Messaging Bus – Data ETL
Data Storage Layer
Data Assets
Knowledge Models
EHR
Documents
Sensor
Other
Bio
Integrated Data Platform
Data Service
Annotate
Correlate
Classify
Data Models
Analytical Layer
Clinical Decision Support System
Analytics Data Mart
Databases
Data Warehouse
Dependent Data Marts
Knowledge Base
APIS, Information Services
Discovery & Analytics
Reports
- Dashboard
Data Mining
- Text mining
- Statistical Modeling
Modeling & Analytics
- Predictive
- Prescriptive
Discovery
- Search
Real Time Apps
- Alerts
Cognitive Computing
- Machine Learning
User Interface
Applications & Prototypes
User Interface & Visualization
Data Virtualization
Metadata & Data Standards
Federated Access & Delivery Infrastructure (FADI)

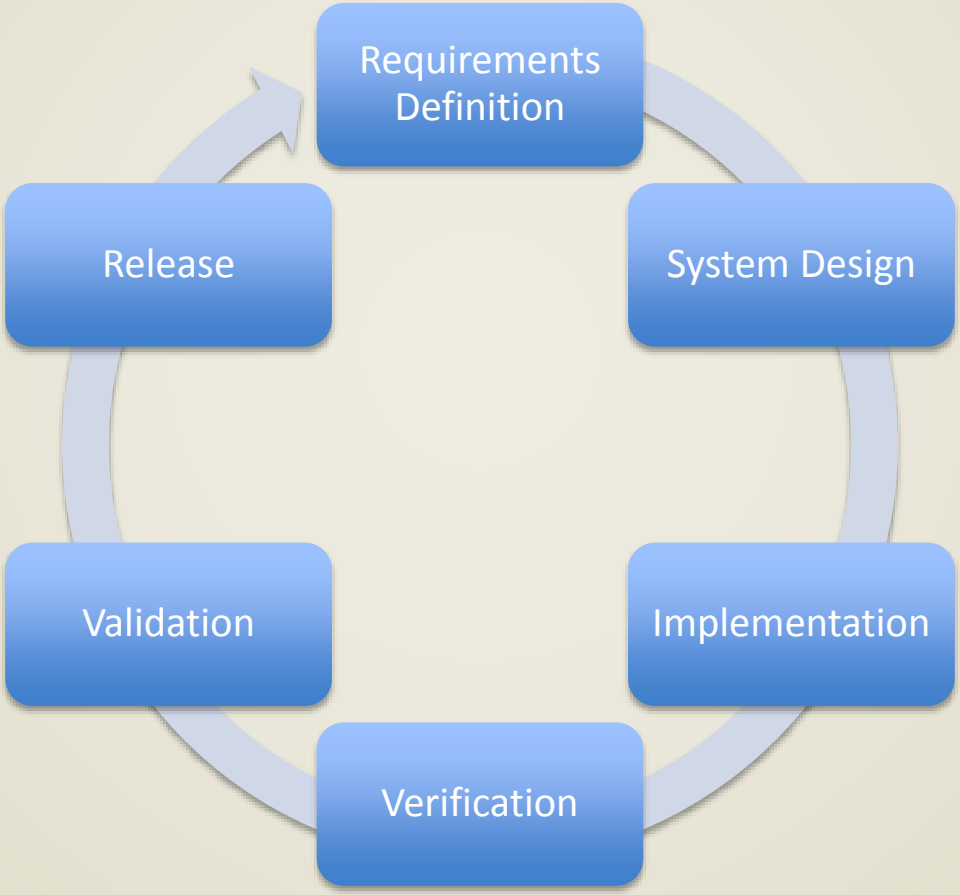
Development Roadmap

- FY16
  - Establish Fundamental Process Requirements that Inform Architecture Planning
  - Build Messaging Protocols to access various Heterogeneous Source Data
  - Data Storage, Data Management, Enterprise Facilitation
  - Prototypes and Visualization under Parallel Development
- FY17
  - Advance FY16 Capabilities
  - Data Integration, Data Services Understood and Improved
  - Analytics Platform Development and Integration
  - Prototypes Enhancements and Additions
  - Articulate Specific Requirements for “Proving Ground” FTOs
- FY18 and beyond
  - Further Analytics Prototypes with Applications
  - Analyze Specific Flight Vehicle Constraints and Assets
  - Propose Modifications of Development following Formal Reviews

FY16 Tasks: Architecture Implementation

- Identify and Develop Fundamental Architecture Elements
  - Determine data architecture sub-systems
  - Identify middleware capabilities
  - Determine knowledge bases; expert system integration
  - Develop data storage & reference databases
  - Articulate data/Information visualization techniques
  - Develop/Identify data analytics methods
    - ➢Algorithm development and integration

Iterative Release Cycle Process



ExMC EMSD Lessons/Observations

- What worked well
  - Configurable open source EHR, access to all patient data
  - Increased technical collaboration across multi-center partners
  - Demonstrated integrated data management capability
- Challenges/limitations
  - Constraints did not allow adherence to planned architecture
    - Utilized existing ISS tool and commercial components
  - Data complexities
    - Stored all data in one location (EHR)
    - Required data streaming
  - Relied on file transfer, commercial products resulting inconsistent data formats, did not enrich data
  - Procedures based on existing ISS processes that were complex, step wise procedures hard coded

ExMC EMSD Lessons Incorporated

- What ExMC is doing differently going forward?
  - Strategic implementation roadmap to guide project completion
  - Adherence to high level architecture but validate and revise
  - Continuous iterative development release cycle
  - Develop scalable data integration, transformation model and storage methodology
  - Data stored in standardized format and semantically linked
  - Build data architecture with foundational medical decision support components
  - Strategic storage of EHR data, consistent with EHR architecture

Summary

- Medical data architecture system for long duration ExMC risk mitigation presented
- High level elements, layered architecture, implementation, development roadmap & iterative release cycle discussed
- Foundational architecture includes EHR, knowledge bases, standard data format & predictive analytics
- EMSD lessons learned have been incorporated into design