412TW-PA-18341

TELLING THE T&E SPECTRUM STORY USING ANALYTICS

MICHAEL K. PAINTER
KARTHIC MADANAGOPAL
KANNAN SWAMINATHAN

AIR FORCE TEST CENTER
EDWARDS AFB, CA

NOVEMBER 2018

4
1
2
T
W

412TH TEST WING
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
20-06-2018	Briefing Slides	5-8 November 2018

4. TITLE AND SUBTITLE
Telling The T&E Spectrum Story Using Analytics

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Michael K. Painter
Karthic Madanagopal
Kannan Swaminathan

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
Knowledge Based Systems, Inc.
1408 University Dr. East
College Station, TX 77840

8. PERFORMING ORGANIZATION REPORT NUMBER
412TW-PA-18341

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
412th Test Wing
195 E Popson Ave
Edwards AFB CA 93524

10. SPONSOR/MONITOR'S ACRONYM(S)
N/A

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release A: distribution is unlimited.

13. SUPPLEMENTARY NOTES
International Test and Evaluation Association (ITEA)
The Tuscany Suites
255 E. Flamingo Road
Las Vegas, NV 89169

14. ABSTRACT

There continues to be growing pressure to sell off spectrum currently allocated for defense purposes in favor of private sector applications. These pressures come at a time when Department of Defense (DoD) spectrum needs are growing at an exponential pace, raising concerns that we will soon reach a point where they can no longer be met. In response, the Range Commanders Council (RCC) Frequency Management Group (FMG) developed a baseline set of standard metrics to measure spectrum utilization, demand, efficiency, and operational effectiveness. Using this standard (RCC 707-14) as a foundation, a Spectrum Management Metrics Toolkit (SMMT) has been developed to calculate, plot, and display these metrics. The challenge now is determining how to successfully apply these metrics to inform and construct the arguments needed to maintain access to the needed spectrum.

The purpose of this presentation is to describe progress toward the development of a methodology and a set of analytics based on the RCC standard to build such a compelling narrative. The methodology is based on a data analytics and communication concept, called "Story Points," which seeks to guide users in the discovery, composition, and delivery of targeted narratives and supporting graphics derived through mining available data sources.

15. SUBJECT TERMS
Test and Evaluation(T&E), Spectrum, Range Commanders Council(RCC)

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			412 TENG/EN (Tech Pubs)
Unclassified	Unclassified	Unclassified	None	24	**19b. TELEPHONE NUMBER** *(include area code)* 661-277-8615

Test and Evaluation/Science and Technology Program

Spectrum Management

Spectrum Efficiency Through Metrics (SETM)

Acknowledgment of Support: This project is funded by the Test Resource Management Center (TRMC) Test and Evaluation/Science & Technology (T&E/S&T) Program through the U.S. Army Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI) under Contract No. W900KK-16-C-0018. The Executing Agent and Program Manager work out of the AFTC.

Telling the T&E Spectrum Story Using Analytics

Michael K. Painter, P.E.

Karthic Madanagopal

Kannan Swaminathan, P.E.

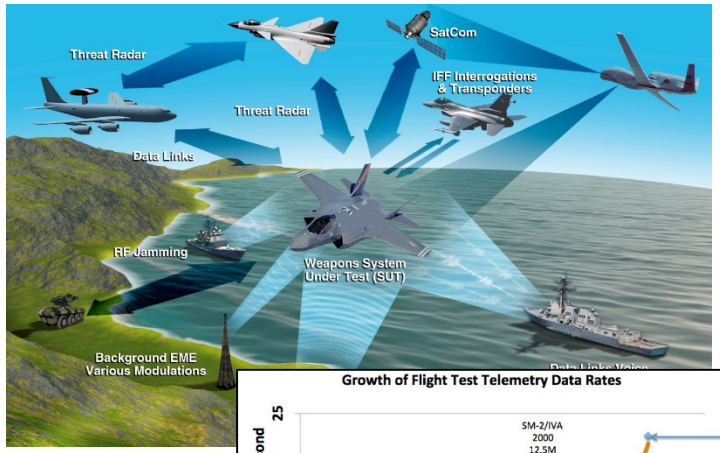
Knowledge Based Systems, Inc.

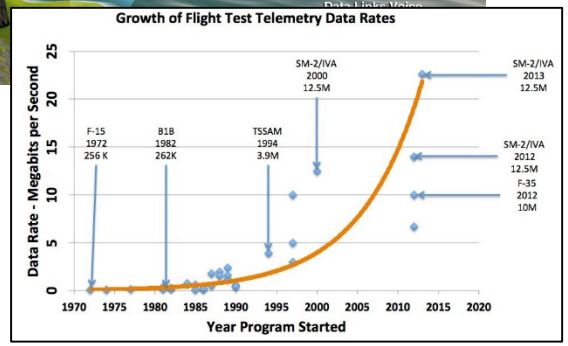
Charles H. Jones, PhD

C. H. Jones Consulting, LLC

Introduction

- Growing pressure to sell off spectrum currently allocated for defense purposes.
- Lack of well-defined metrics and tools to:
  - Account for *actual* versus *scheduled utilization* of the spectrum that is allocated
  - Estimate current and future spectrum needs
  - Quantify the implications of spectrum loss.



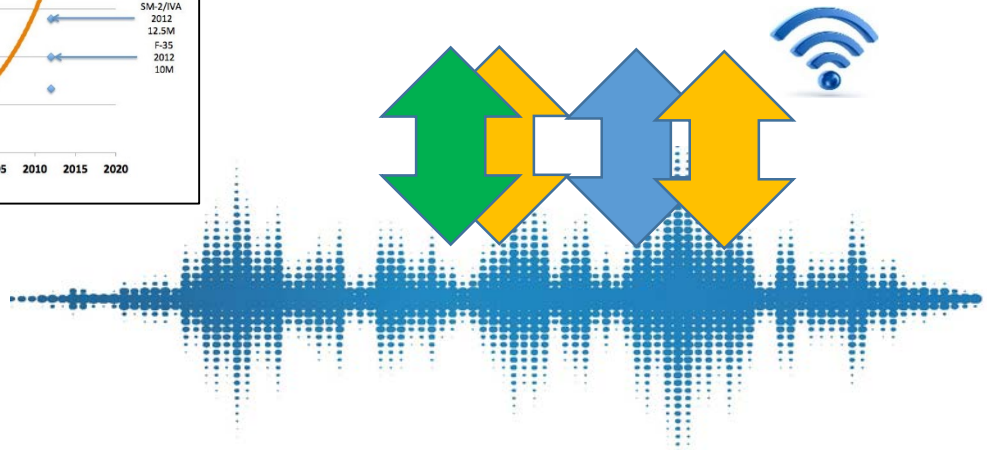


IOT

Satellite Radio

Cellular Services

Wireless Internet



- Developments like the RCC FMG frequency management metrics standard and tools like the Spectrum Management Metrics Toolkit (SMMT) seek to help better manage and defend needed T&E spectrum.

Spectrum Management Metrics Toolkit (SMMT) Overview

SMMT Prototype Basics

- Enterprise-level, web-based application
  - Angular 2.0 front end / Node JS back end
  - SQLite or MS-SQL database engine
- Authorized access through “single-sign-on” (SSO) (Active Directory)
  - Also supports secure deployment using https:\\ with basic authentication
- Features:
  - Analysis data from various data sources ingested through an intelligent “drag-and-drop” interface
  - User-defined (persistable) filters to support focused analysis purposes
  - Metrics calculation and display ‘widgets” using various chart types (e.g., 3D graphs, bar charts)
  - Supports “cross-filtering” or “brushing and linking” across metrics widgets, meaning that a change made in the filtering criteria for one widget is automatically propagated to related metrics widgets
  - Personalized dashboards composed from user-selected widgets

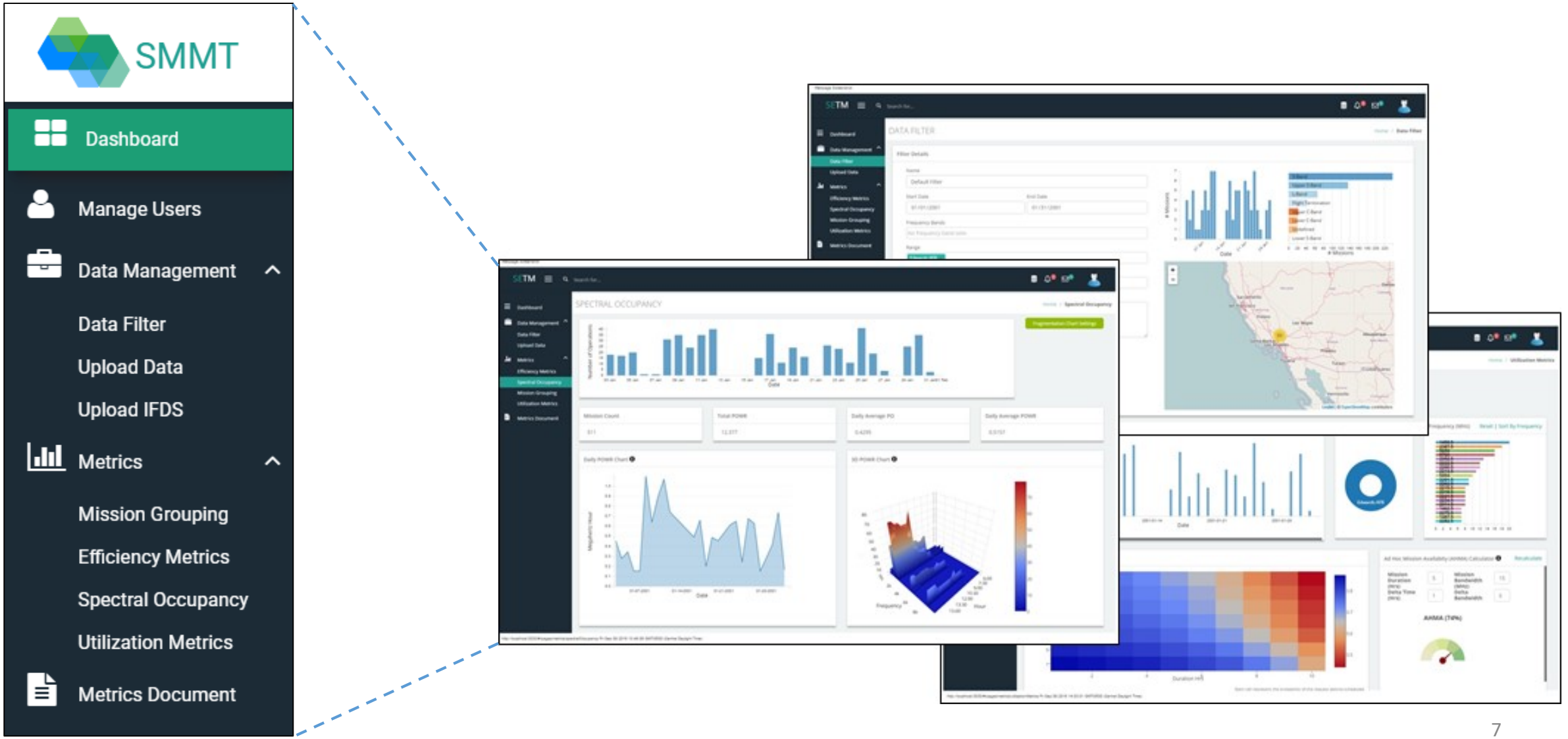
Targeted RCC FMG Metrics By Metric Category

- Spectrum Occupancy
- Spectrum Utilization
- Frequency Request Groupings
- Efficiency
- Spectrum Reuse
- Frequency Scheduling Operational Metrics
- Predictive and “What-if” Metrics

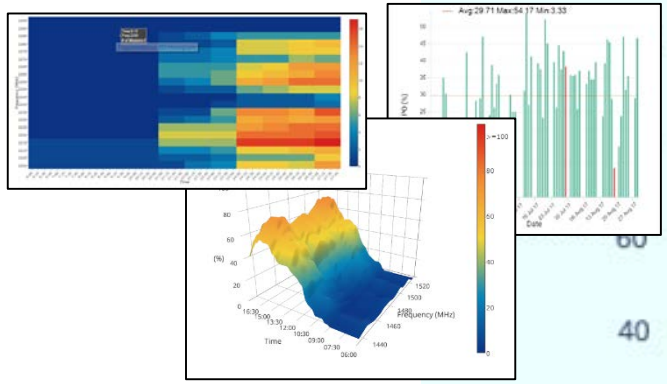
Metric Type	Metric
1. Utilization	1.1.Ad Hoc Mission Availability (AHMA)
	1.2.Typical Missions
	1.3.Average Typical Mission Availability (ATMA)
	1.4.Spectrum Utilization
	1.5.Average Spectrum Utilization
	1.6.3D Average Daily Utilization Chart
	1.7.2D Spectrum Utilization Projections
2. Spectrum Reuse	2.1.Operational Interference
	2.2.Mutual Area of Use
3. Spectral Occupancy	3.1.Percent Occupancy With Reuse (POWR)
	3.2.Average POWR (Daily, Monthly, Yearly)
	3.3.3D Average POWR Chart
	3.4.Percent Occupancy (PO)
	3.5.Average PO
	3.6.3D Average PO
	3.7.Percent Multiple Use (PMU)
	3.8.Frequency Reuse Ratio (FRR)

Metric Type	Metric
4. Efficiency	4.1.Scheduled Bandwidth vs. Necessary Bandwidth
	4.2.Mission Modulation Efficiency (MME)
	4.3.Average MME (AMME)
	4.4.Modulation Method Ratio (MMR)
	4.5.Mission Spectrum Efficiency (MSE)
	4.6.Average MSE
	4.7.Average Spectral Band Efficiency (ASBE)
	4.8.Bits Sent
	4.9.Bits Sent per MH
5. Metrics by Mission Groupings	USES OTHER METRICS WITH FOCUS ON A SINGLE OPERATION • Total Duration • Total MH
6. Scheduling Operational Metrics	6.1.Requests Authorized
	6.2.Assignments Canceled, Delayed, or Rescheduled
	6.3.Assignment and Operation Statistics
7. Predictive, What If, Metrics	7.1.Spectrum Movement Analysis
	7.2.New Program Impact Analysis

SMMT “Breadboard” Prototype Interface

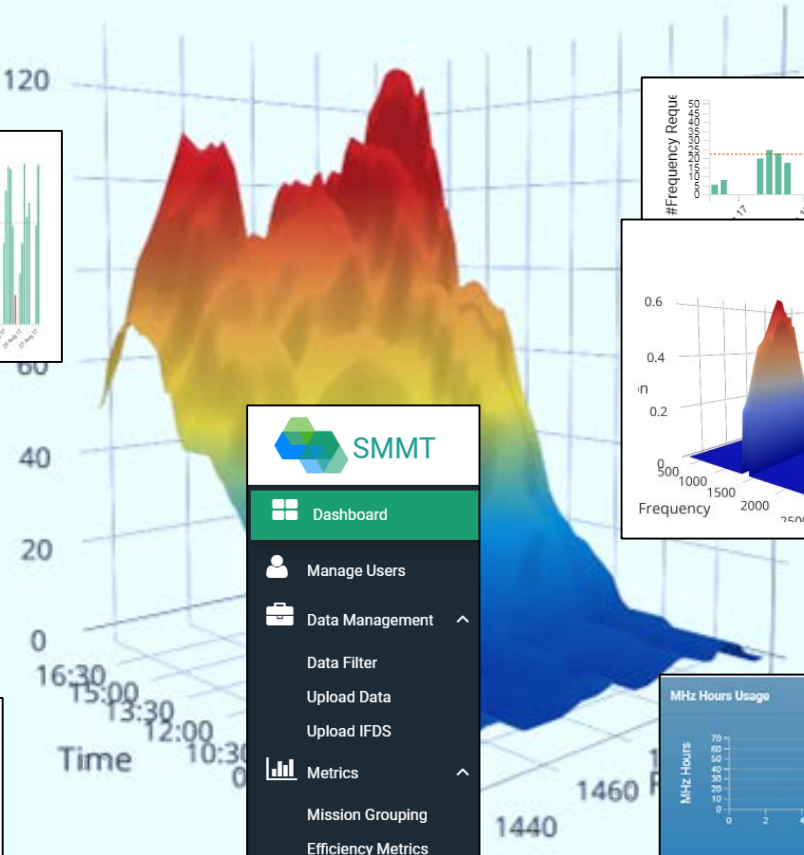


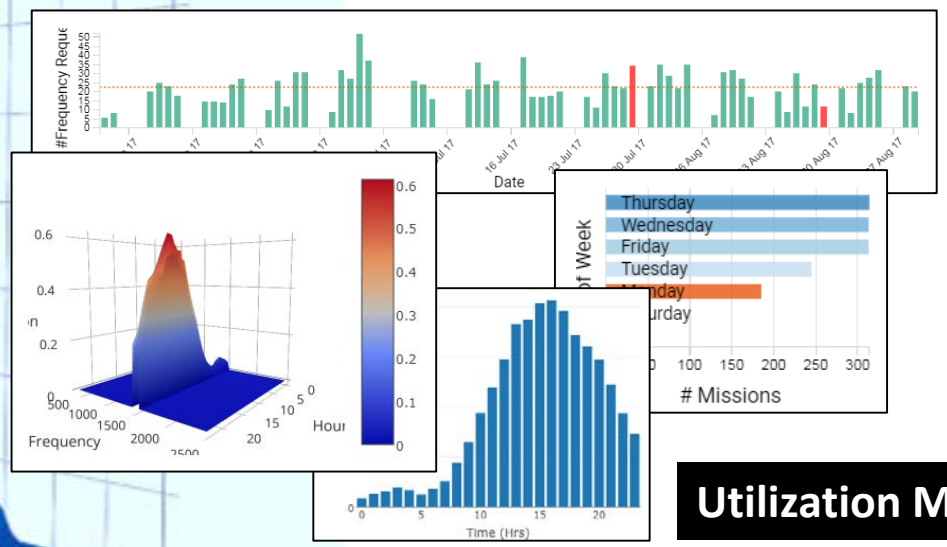
SMMT Metrics



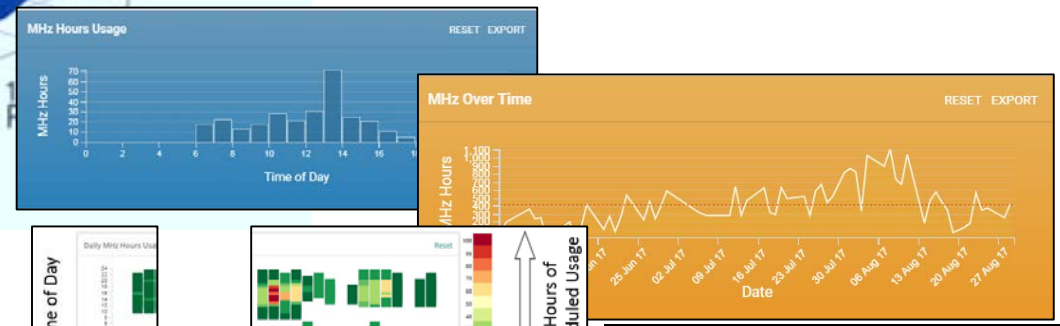
Occupancy Metrics

Efficiency Metrics



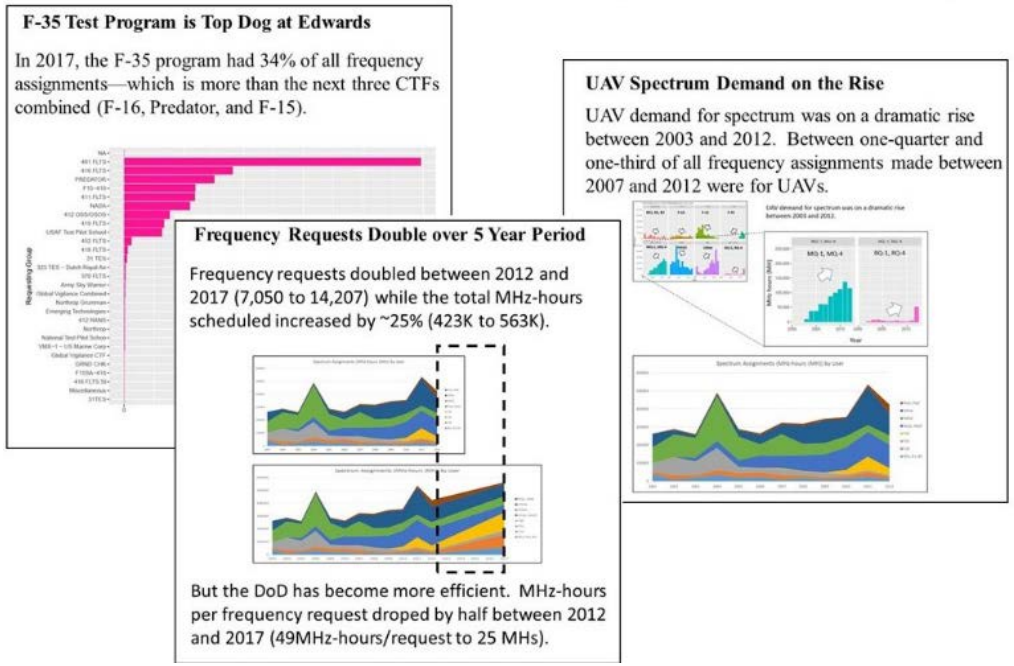


Utilization Metrics



Mission Grouping Metrics

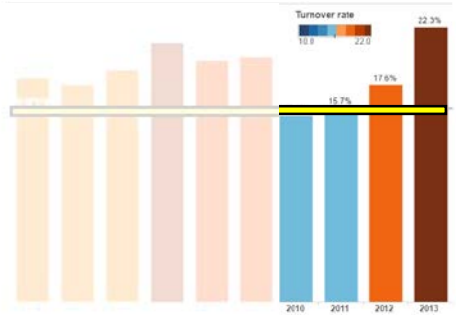
Narrative Visualization



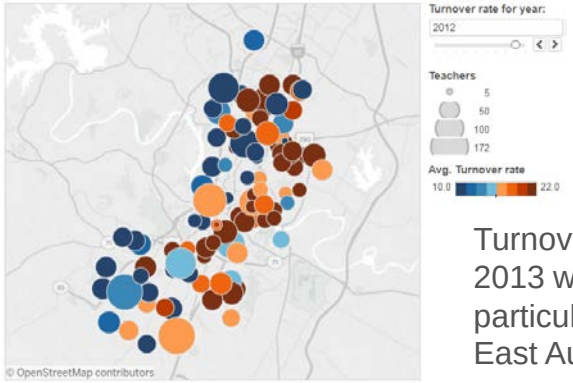
- Metrics can be powerful—if they are presented and embellished as part of a narrative that tells a compelling story or argument.
- "Narrative visualization" is an extension of a data analysis and communication concept called "Story Points."
- Goal is to support users in building a narrative and supporting graphics based on findings in the data (e.g., patterns, trends, anomalies).

Narrative Visualization Elements

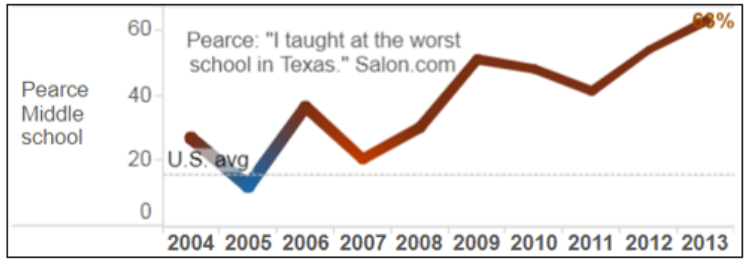
< Austin's teacher turnover is above the national average. 1 | And, turnover rates have become worse in recent years 2 3 | The problem is particularly acute in some schools. 4 | And city-wide, the problem isn't getting better. 5 >



Turnover was above the national average for most years.



Turnover rates in 2013 were particularly bad in East Austin



Some schools appear to be getting worse.

The [measure] (e.g., teacher turnover) for some period is "above/below" some [benchmark value]. 1

Comparison to benchmark

There is an upward / downward trend in the [measure] for the specified period. 2

Recognition of a pattern or trend

Being "above/below" some specified value is a "problem/good thing." 3

An "upward /downward" trend is a "problem/good thing." 3

Value judgment

The "negative/positive" condition represented by the [measure] is "common/uncommon" among members of a specified set. 4

Extent or range of involved sets

Prognosis 5

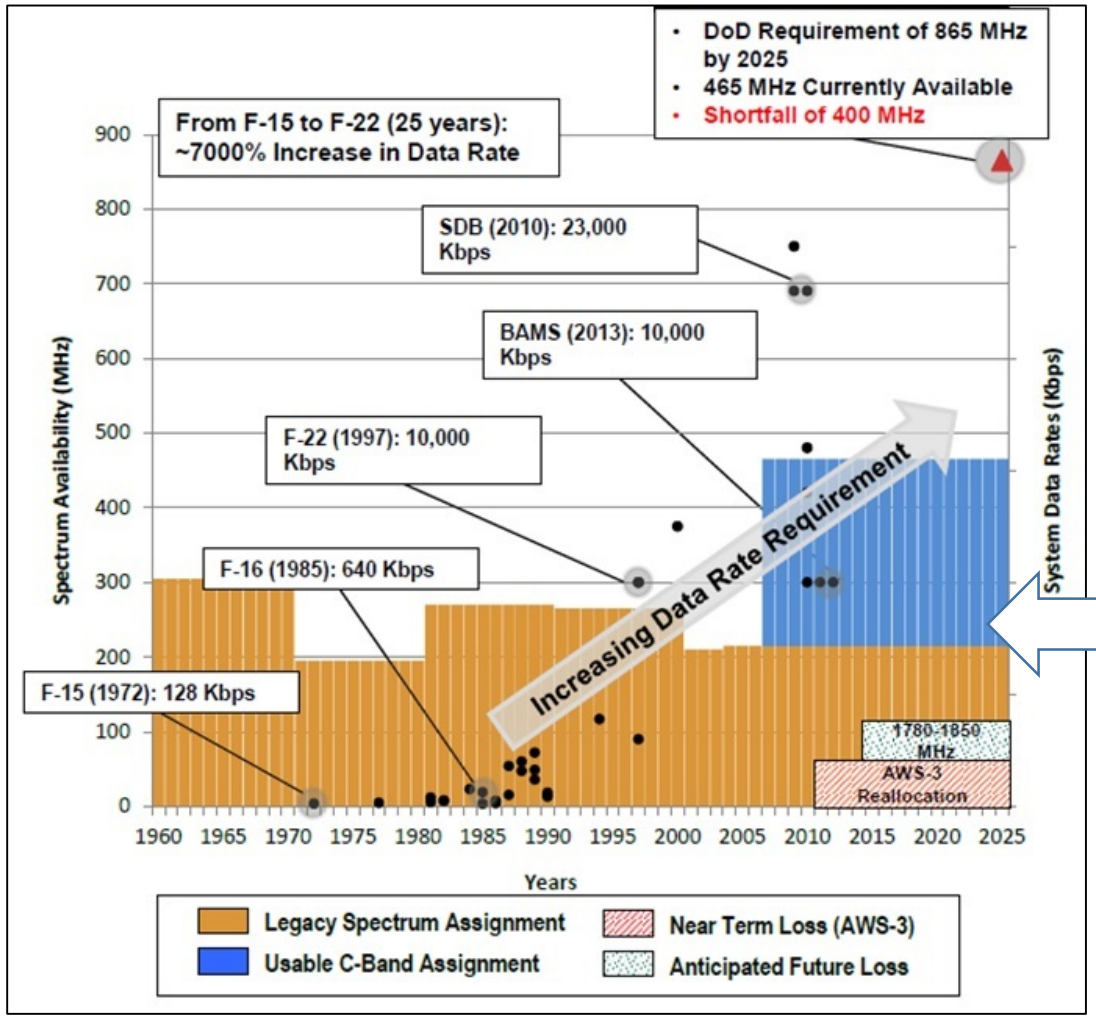
- Likely outcome
- Getting better, not changing, getting worse

Potential cause(s) 6

EX #1: Rising Pressures for More T&E Spectrum

Data rate requirements continue to rise at an accelerating pace.

Data rates increased by 7,000% over the 25 years between the F-15 and F-22 programs.



Even with the addition of C-band, current projections indicate a major shortfall of 400 MHz by 2025.

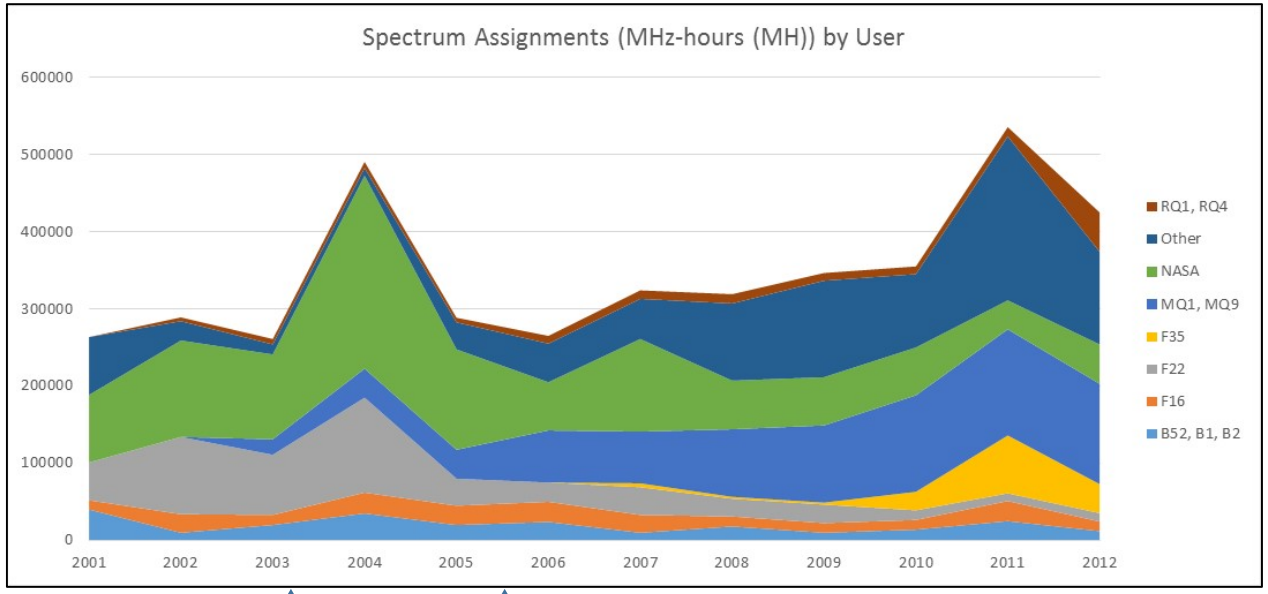
Comparison to benchmark | Recognition of a pattern or trend | Value judgment | Extent or range of involved sets | Prognosis | Possible cause(s)

Example #0: NASA More than Doubles Its Frequency Use (MHs)

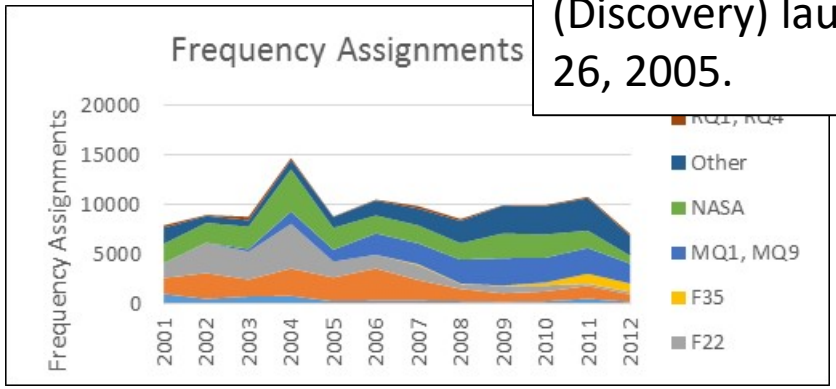
The number of frequency assignments for NASA testing doubled in 2004.

MHs for NASA tests in 2004 increased 2.5 times their historical average (~250,000 MH vs. average of ~100,000 MH per year).

NASA tests accounted for 29% of the total MHs consumed between 2001 and 2012, peaking at 51% of the assignments made in 2004.



Columbia disaster Discovery (STS-114)



The spike in NASA's use of spectrum in 2004 may have been a side-effect of the Columbia disaster (Feb 1, 2003). The Space Shuttle fleet was grounded for more than two years while safety measures were added, which required testing before STS-114 (Discovery) launched on July 26, 2005.

Comparison to benchmark

Recognition of a pattern or trend

Value judgment

Extent or range of involved sets

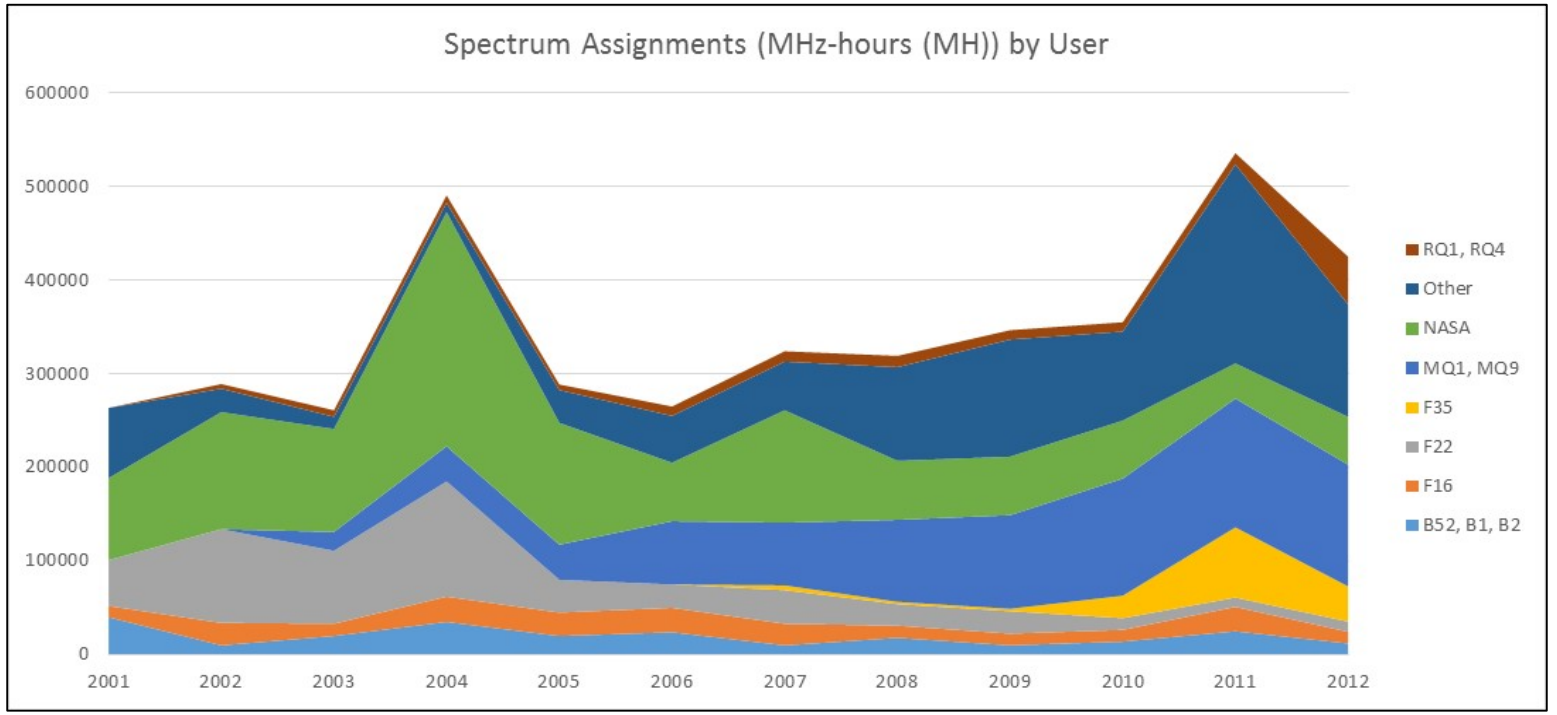
Prognosis

Possible cause(s)

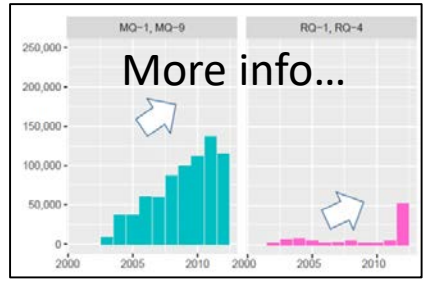
EX #1: Steady Increase in MH Consumption

Overall, MHz-hours (MH) scheduled across CTFs steadily increased between 2001 and 2012.

The biggest users early in the period were NASA and the F-22 programs, which later shifted to UAVs and "other" programs.



Assuming current trends continue, one can expect moderate growth in spectrum usage for the near future.



Comparison to benchmark

Recognition of a pattern or trend

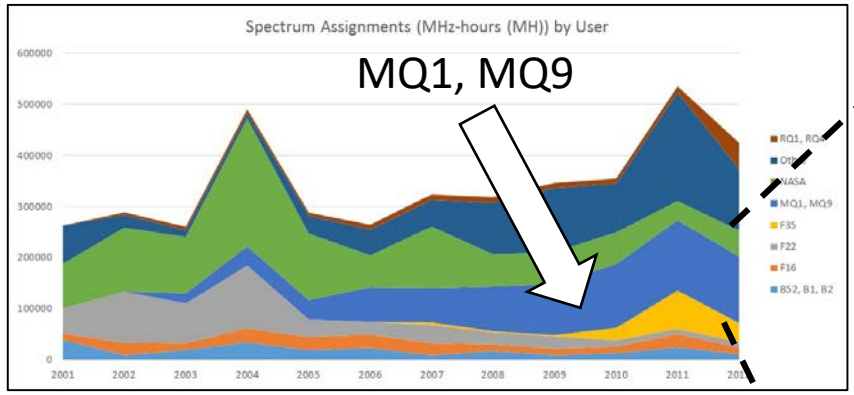
Value judgment

Extent or range of involved sets

Prognosis

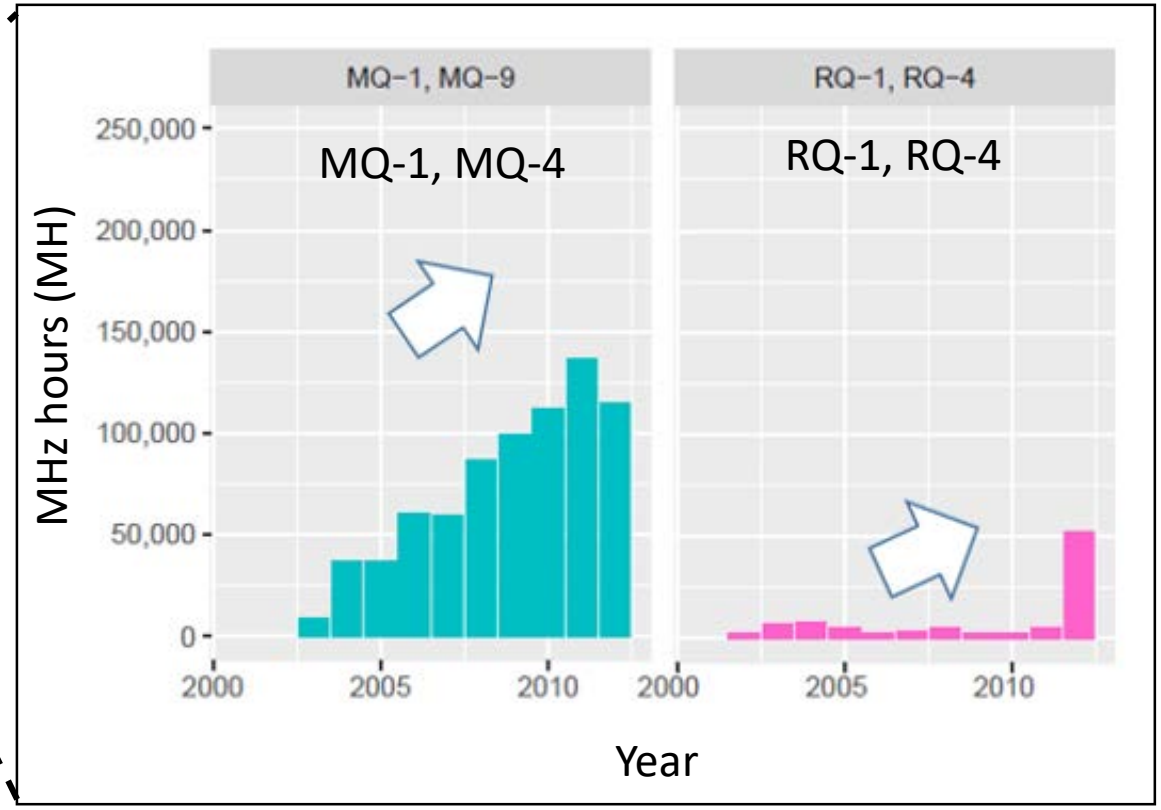
Possible cause(s)

EX #1 (cont.): Steady Increase in MH Consumption



Spectrum use for UAV testing was on a dramatic rise between 2003 and 2012.

UAV demand for spectrum accounted for over 30% of all requests by count and 42% of all MHz-hours in 2012.



Comparison to benchmark

Recognition of a pattern or trend

Value judgment

Extent or range of involved sets

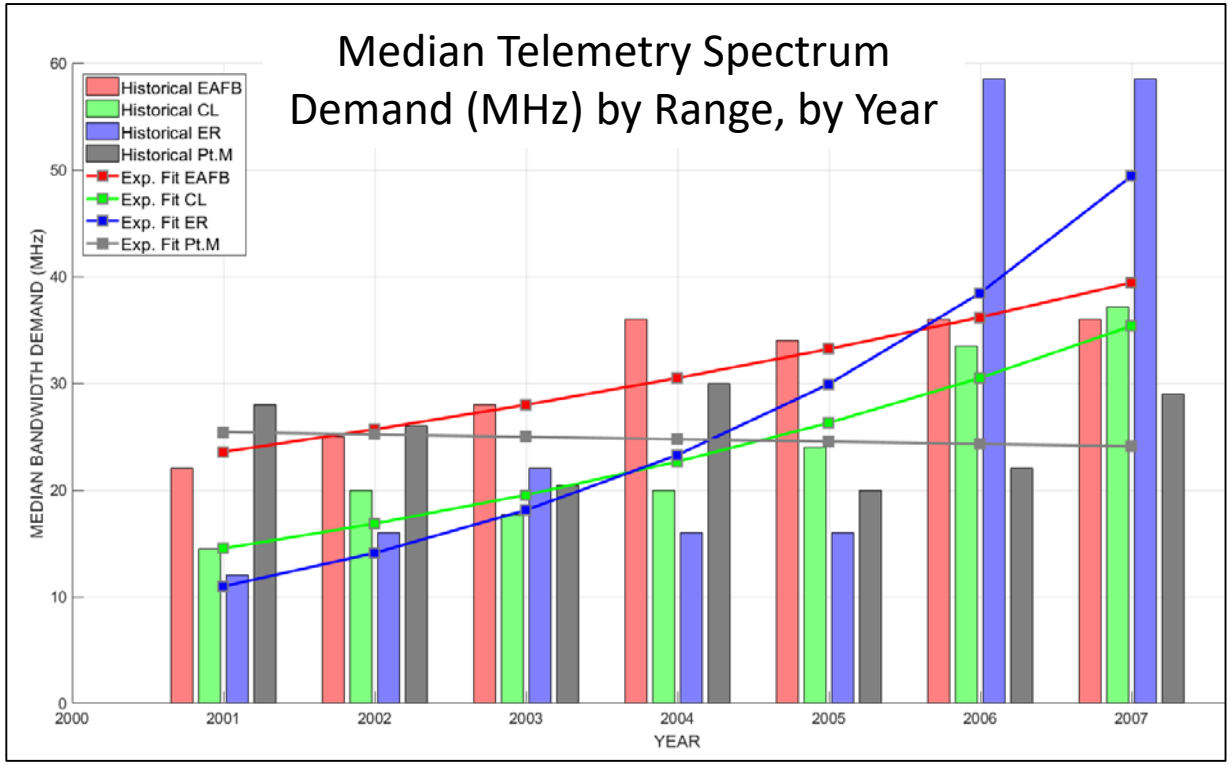
Prognosis

Possible cause(s)

EX #2: Spectrum Demand Rising for Follow-on Testing

Spectrum demand for follow-on testing at EAFB (ignoring developmental testing) is on track to double every 9 years.

Other test ranges (e.g., China Lake, Echo Range, Point Mugu) had different growth rates in telemetry spectrum demand.



Considering the growth in spectrum demand for developmental testing, we can expect overall trends to increase at an accelerating pace.

Comparison to benchmark

Recognition of a pattern or trend

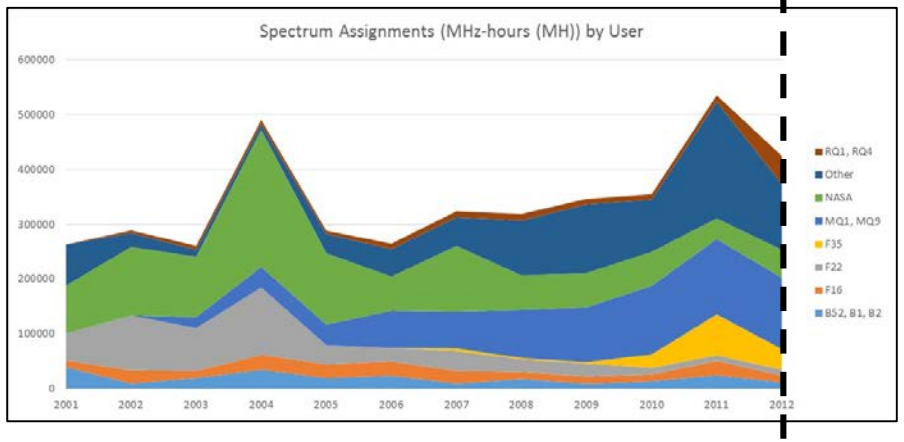
Value judgment

Extent or range of involved sets

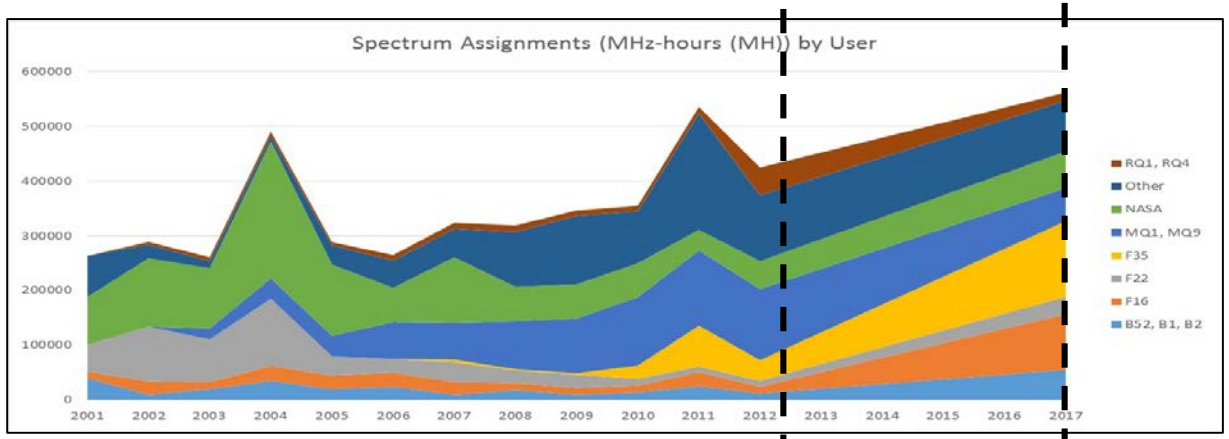
Prognosis

Possible cause(s)

Example #3: Spectrum Assignments Double While MHs Are Cut by a Third



Five years passed…



The total number of spectrum assignments doubled between 2012 and 2017 (7,050 to 14,207).

The total MHz-hours scheduled increased by ~25% between 2012 and 2017 (423K to 563K).

MHz-hours per frequency assignment was reduced by a third between 2012 and 2017 (60MHz-hours/request to 40 MHs).

More assignments + less BW per assignment means more efficient use of spectrum.

Comparison to benchmark

Recognition of a pattern or trend

Value judgment

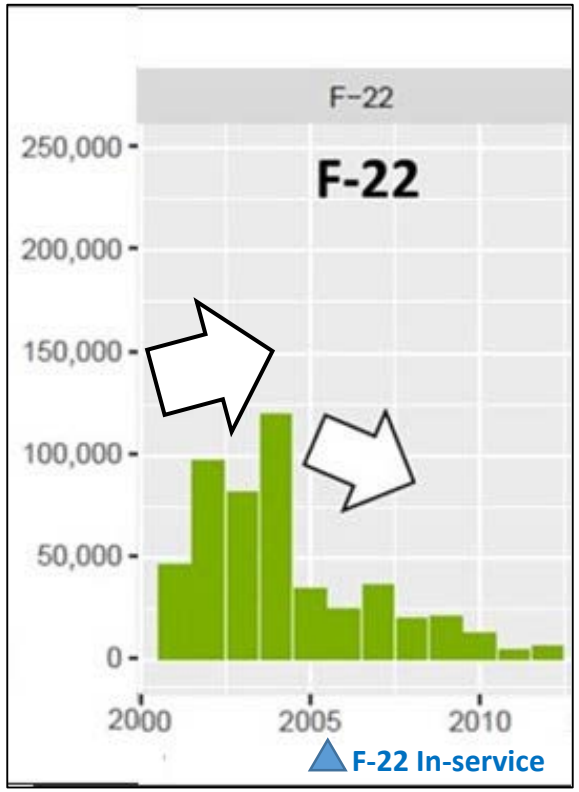
Extent or range of involved sets

Prognosis

Possible cause(s)

EX #4: F-22 Completes Developmental Testing

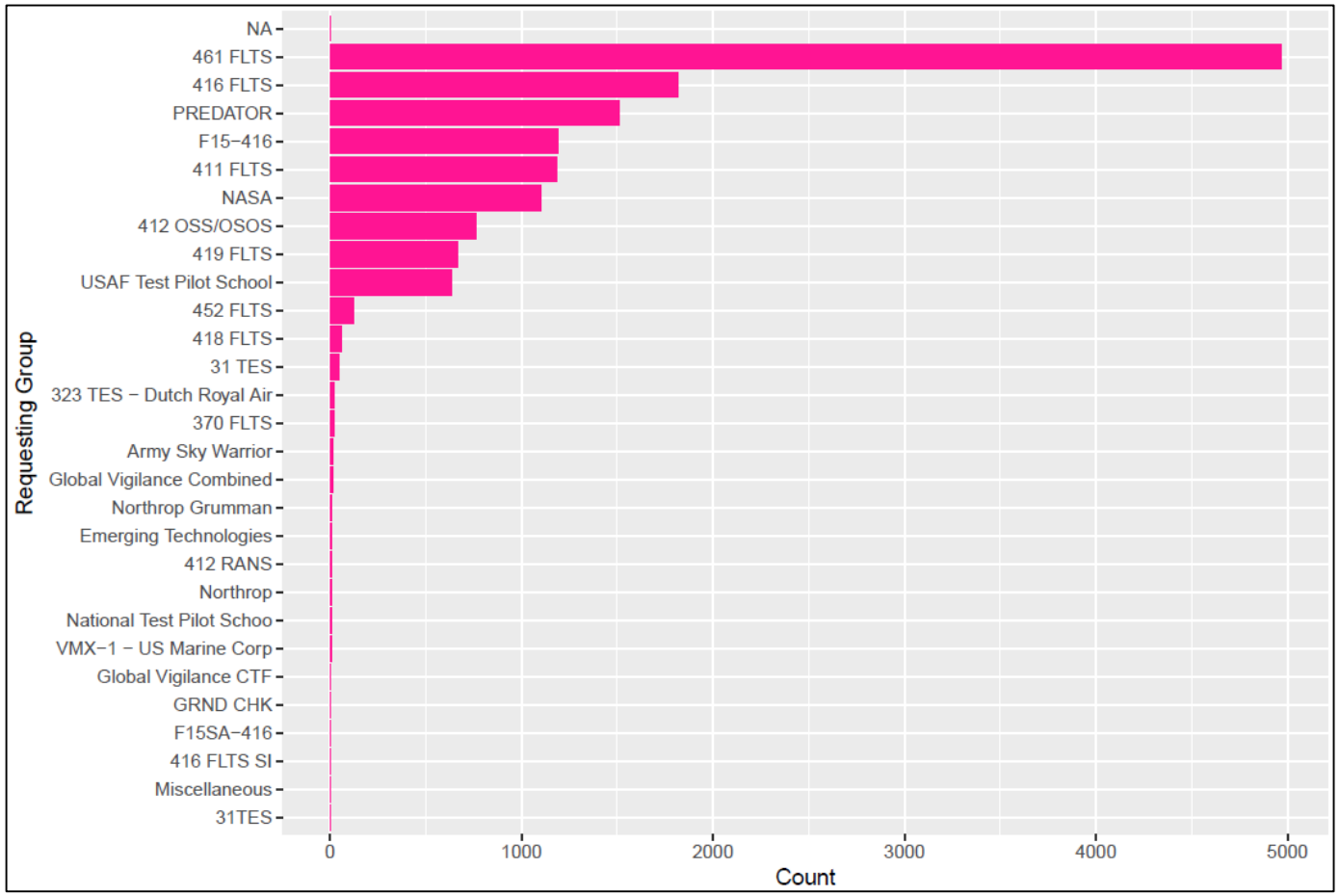
Spectrum use by the F-22 CTF rose significantly over a period of four years before a precipitous drop that started in 2005.



These dramatic shifts in spectrum use coincided with the end of F-22 developmental testing phase prior to going into service in early 2006.

Comparison to benchmark | Recognition of a pattern or trend | Value judgment | Extent or range of involved sets | Prognosis | Possible cause(s)

Example #5: F-35 Test Program is Top Dog at Edwards



In terms of the number of frequency assignments, the F-35 test program at the 461st FLTS is the biggest user.

In 2017, the F-35 program had 34% of all frequency assignments—more than the next three CTFs combined (F-16, Predator, and F-15).

Comparison to benchmark

Recognition of a pattern or trend

Value judgment

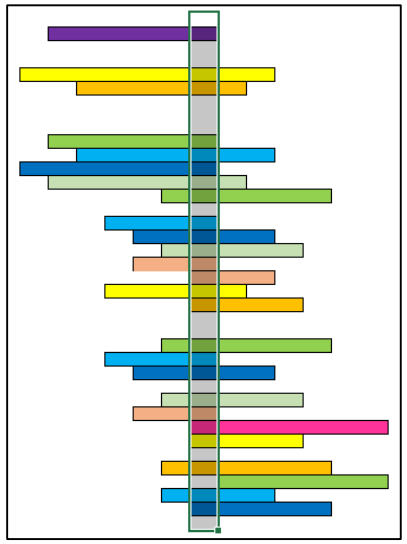
Extent or range of involved sets

Prognosis

Possible cause(s)

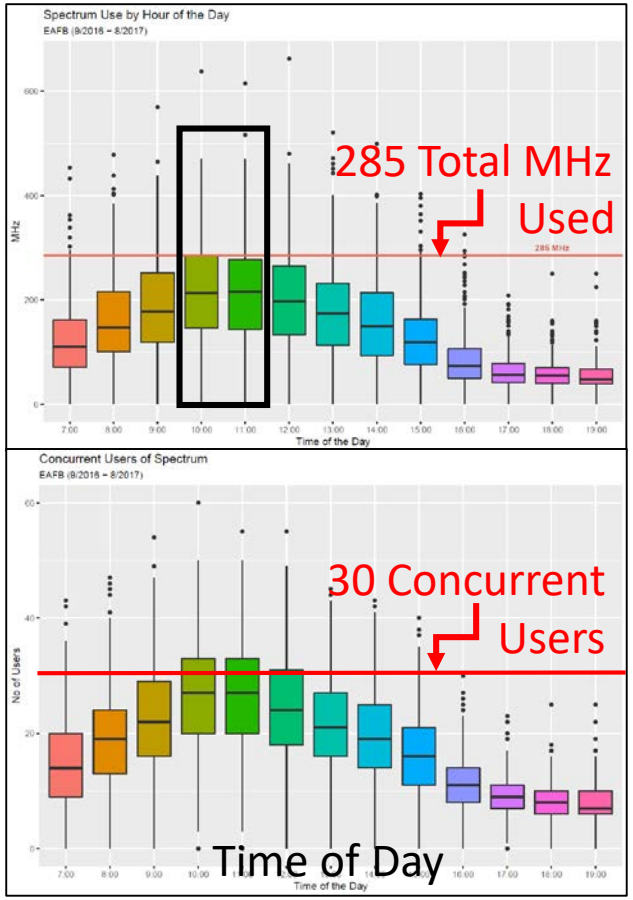
EX #6: EAFB Approaching a Saturation Point

285	MHz available at any one time
9.5	MHz (on average) per request
30	Max # of concurrent assignments



The expected, maximum number of non-overlapping, concurrent frequency assignments that can be supported is 30.

$$\frac{285 \text{ MHz}}{9.5 \text{ MHz per Assignment}} = 30 \text{ Assignments}$$



At EAFB in FY17, the number of concurrent assignments exceeded this threshold between 10AM and noon more than than a third of the time.

From 10AM to noon, on average, the total MHz used at EAFB exceeded the spectrum available by as much as 25%.

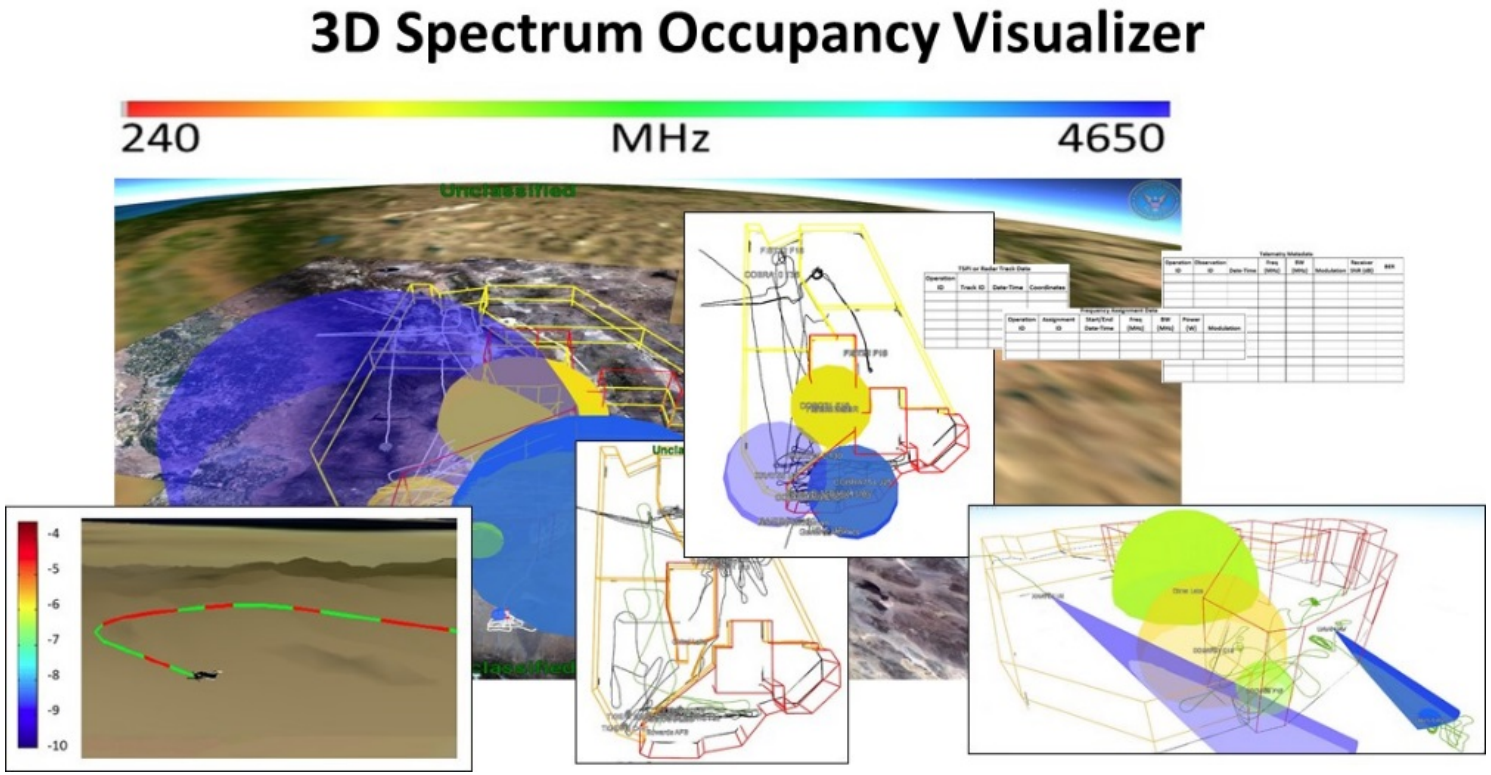
The difference was handled by using the C-band.

Continued increases in spectrum demand may require lengthening test schedules.

Comparison to benchmark | Recognition of a pattern or trend | Value judgment | Extent or range of involved sets | Prognosis | Possible cause(s)

Telling the Story Through Dynamic Spectrum Use Visualization

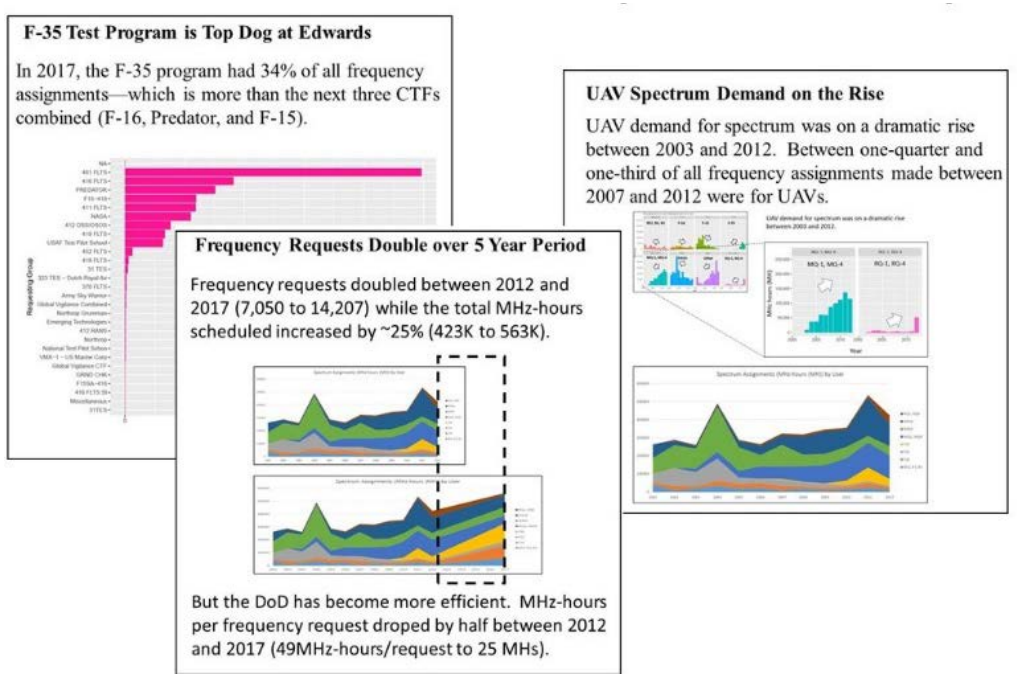
- Experimenting with advanced visualization methods for 3D, dynamic display of a test article's "spectral presence," signal quality, potential interference events, etc.



- Display possible in near real-time or during a-posteriori review.

Summary

- Assured access to electronic spectrum is essential to the success of U.S. military operations.
- Economic pressures to increase commercial spectrum use will continue to threaten further loss of DoD spectrum.



- If the DoD hopes to maintain the spectrum it needs for T&E purposes, it will have to clearly demonstrate both the need for, and responsible stewardship of, T&E spectrum.
- Developments like the RCC's frequency management metrics standard and tools like the SMMT seek to provide the means to better manage and defend needed T&E spectrum.

Contact Information

Mike Painter, P.E. (mpainter@kbsi.com)

Karthic Madanagopal (kmadanagopal@kbsi.com)

Kannan Swaminathan (kswaminathan@kbsi.com)

Charles Jones, Ph.D. (chjonesconsulting@gmail.com)

KBSI Corporate Headquarters

1408 University Drive East, College Station, TX 77840-2335

Phone: 979.260.5274 Fax: 979.260.1965