



Communication Requirements for Cockpit Weather Products (FIS)

*Weather Accident Prevention Annual Project Review
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The Johns Hopkins University
Applied Physics Laboratory
in support of the
NASA Glenn Research Center



Outline

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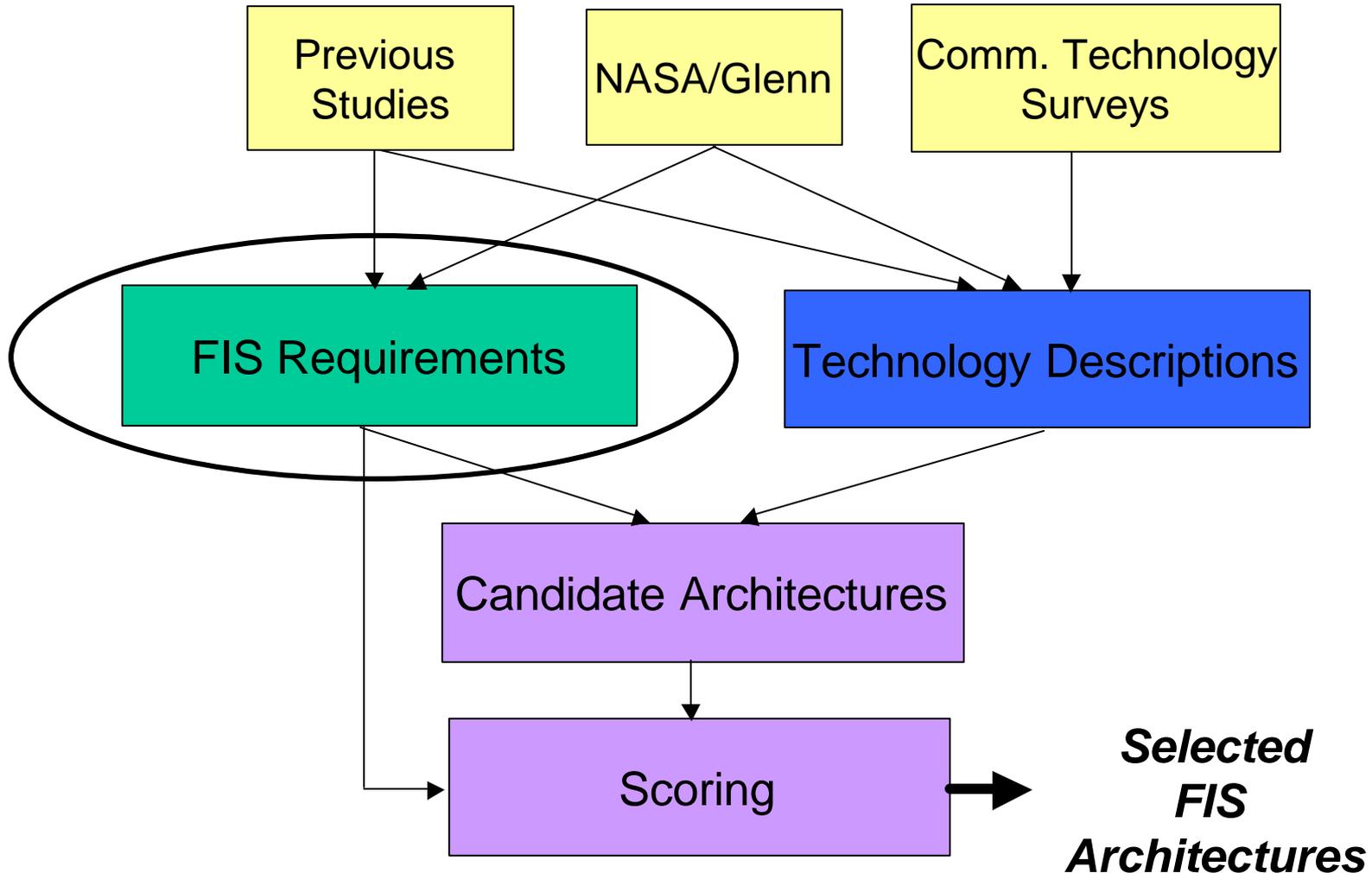


Project Background

- APL is sponsored by the NASA Glenn Research Center (GRC) in the Weather Information Communications (WINCOMM) element of the Aviation Safety Program (AvSP)
 - Communications architecture development
 - Modeling/simulation (M&S)
- Architecture work is focused on two aviation applications:
 - Flight Information Services (FIS)
 - Tropospheric Airborne Meteorological Data Reporting (TAMDAR)
- Current M&S work is focused on Automated Dependent Surveillance -Broadcast (ADS-B) links



Architecture Analysis Process





FIS Requirements

- Requirements were examined across the following areas:
 - Latency
 - Capacity
 - Connectivity/Topology
 - Number of Elements
 - Platform Constraints
 - Coverage
 - Link Availability
 - Cost
 - Traffic Type
 - Protection
 - Spectrum
- Various sources were used to derive estimates

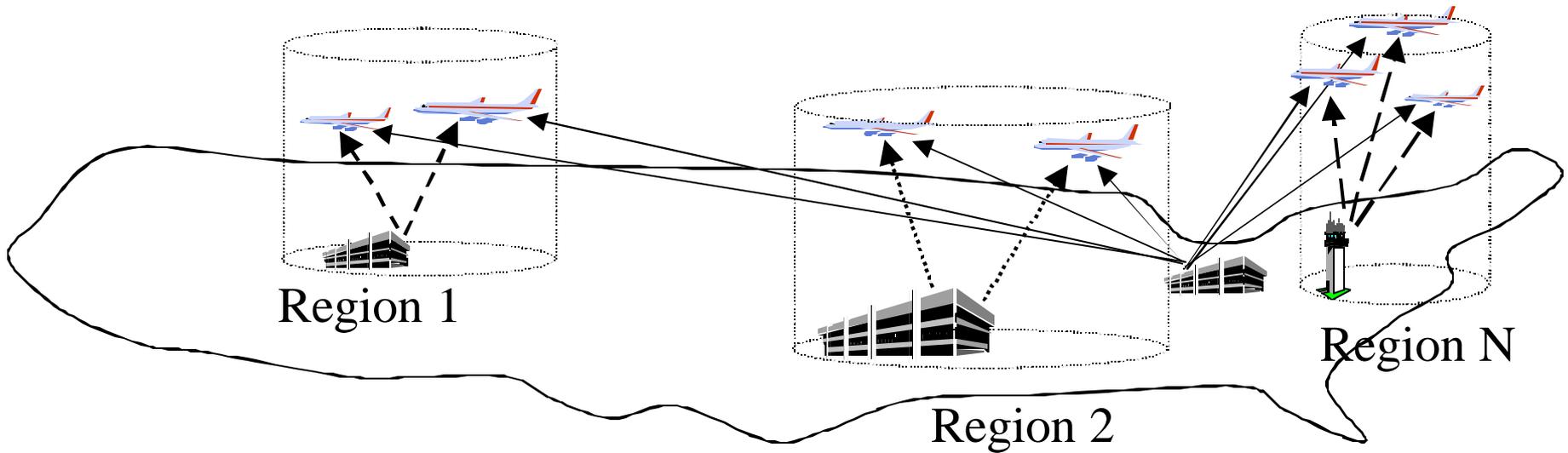


FIS Requirements Analysis

- Based on requirements analysis, FIS capacity is most difficult requirement area to address
- Capacity is a function of required product types, sizes and latency
 - Primarily weather products
 - "NAS Status" also included as part of FIS (e.g., NOTAMs)
- Estimates from other studies vary widely, therefore APL determined a "first principles" estimate



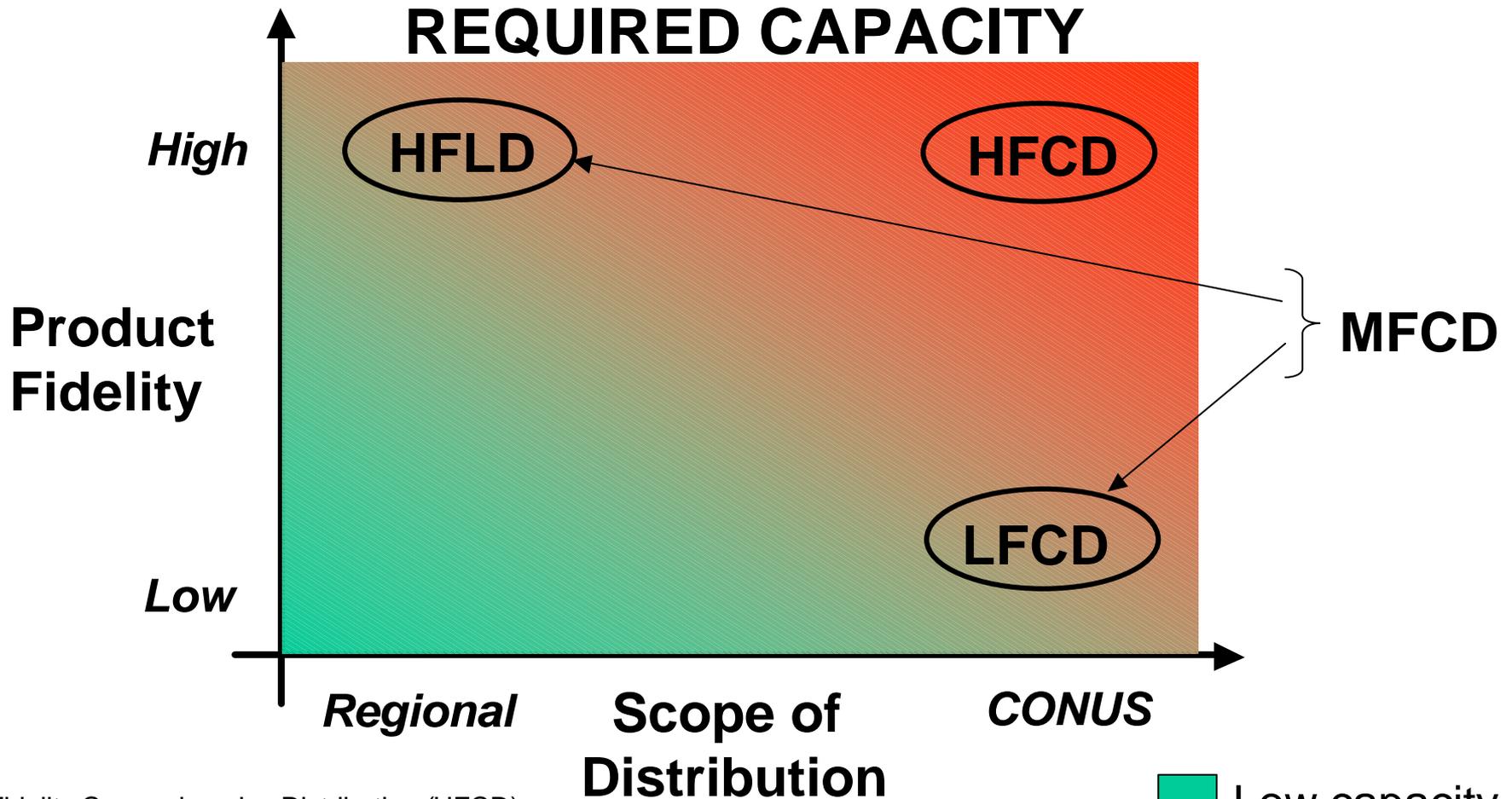
Distribution Approaches (1 of 2)



FIS distribution must consider the need for products with regional and CONUS perspectives



Distribution Approaches (2 of 2)



- High Fidelity Comprehensive Distribution (HFCD)
- High Fidelity Limited Distribution (HFLD)
- Low Fidelity Comprehensive Distribution (LFCD)
- Multiple Fidelity Comprehensive Distribution (MFCD)

- Low capacity
- High capacity



Independent Capacity Estimate

- Utilized publicly available sources for text and graphical FIS-type data
 - Aviation Digital Data Services, FAA, etc.
 - Collected in April/May 2002
- Assumptions/limitations of capacity estimate:
 - Snapshot-in-time analysis
 - Attempted to obtain conservative product instances (e.g., images with weather activity)
 - Off-the-shelf lossless compression used (determining optimal approach beyond current scope)
 - Derived capacity from other posited FIS requirements (5-minute latency, 20% overhead)
- *Should be viewed as first-order estimate, not as conclusive requirement*



Text Product Capacity

- Products
 - METARs, TAFs, PIREPs, AIRMETs/SIGMETs, NOTAMs
 - E.g., METAR "KBWI 241354Z 07008KT 10SM CLR 11/M01 A3031 RMK AO2 SLP264 T01111006"
- Compression
 - BZIP2, GZIP, Stuffit, Compress, ZIP
 - Ratios up to 6.5:1
- Regional load based on approximate LOS communications area

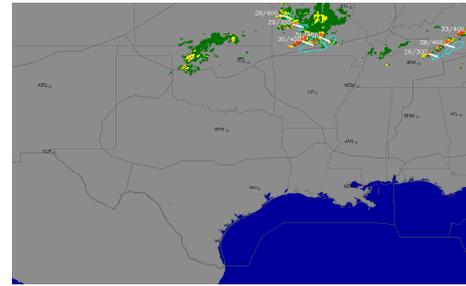
Product	CONUS [bps]	Max. Regional [bps]
METAR	748.8	26.3
TAF	444.8	15.6
PIREP	294.4	15.4
AIRMET/SIGMET	83.2	35.3
NOTAMS	1545.6	232.8
<i>Total</i>	<i>3116.8</i>	<i>325.4</i>



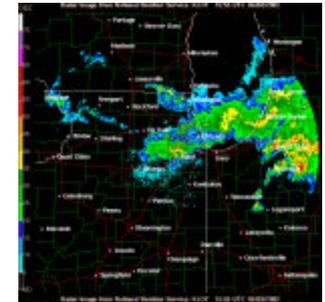
Graphical Product Capacity (1 of 3)

- Products
 - Clouds, Turbulence, Icing, Wind/Temp., Surface Conditions, Convection, Satellite, NEXRAD, Lightning
- Compression
 - PNG
 - Ratios up to 20:1
 - Some much lower (e.g., satellite)
- Regional load based on approximate LOS communications area

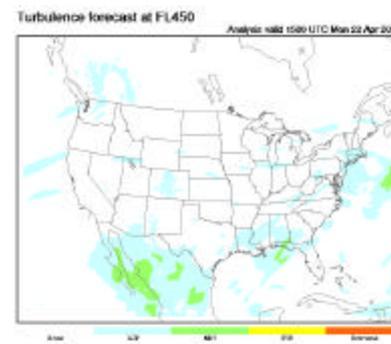
Examples (CONUS and Regional)



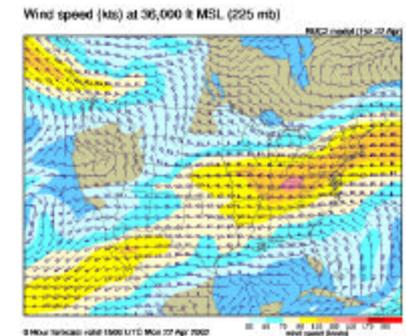
Convection



NEXRAD



Turbulence



Wind



Graphical Product Capacity (2 of 3)

CONUS

Full Set

Reduced Set 1

Reduced Set 2

Product	Size (bytes)	No. of prod. types	Cap. (bps)	No. of prod. types	Cap. (bps)	No. of prod. types	Cap. (bps)
Cloud	21078	20	13490	5	3372	1	674
Turbulence	16390	60	31469	24	12588	2	1049
Icing	19304	19	11737	16	9884	4	2471
Wind and Temp.	39995	528	675756	96	122865	48	61432
Surface Conditions	27910	5	4466	1	893	1	893
Convection	21996	1	704	1	704	1	704
Satellite	805241	2	51535	2	51535	2	51535
NEXRAD	26277	1	841	1	841	1	841
Lightning	8234	1	263	1	263	1	263
Total			790261		202945		119862

- 68 kbps without satellite
- Wind and Temp may warrant further pruning (could reduce to 38 kbps)



Graphical Product Capacity (3 of 3)

Regional

Product	Size (bytes)	Number of product types	Capacity (bps)	Number of product types	Capacity (bps)
Convection	16576	1	530	1	530
Satellite	355692	2	22764	0	
NEXRAD	32121	1	1028	1	1028
Total			24322		1558



Aggregation

- To obtain FIS capacity:
 - Text and graphical products must be aggregated
 - CONUS and regional products must be aggregated with consideration of distribution method (HFCD, MFCD)
- Results
 - HFCD: 183 kbps - 1406 kbps
 - MFCD:
 - 38 kbps - 790 kbps (CONUS)
 - 1.3 kbps - 24.6 kbps (regional)



Comparison with Other Studies

Source	MFC D		HFC D
	Regional ¹	CONUS	CONUS
DO-237 ²	19.6 bps	9.8 kbps	19.6 - 39.2 kbps
LM ²	194.5 bps	207 kbps	304 - 499 kbps
SAIC ³	200-900 bps	N/A	248 kbps
LL	220 bps	N/A	N/A
APL	1.3-24.6 kbps	38 - 790 kbps	183 - 1406 kbps

- Notes
 - 1: Region sizes are not necessarily uniform between estimates
 - 2: Estimate shown utilize the DO-237-recommended 3:1 compression
 - 3: Based on LM compression (typically well above 10:1), larger overhead (estimates could not be independently verified)
- Reasons for differences:
 - Product composition (e.g., DO-237 more focused on text, rather than graphical products)
 - Compression in SAIC estimates (based on LM study) greater than typical found in APL assessment



Open Research Questions

- Product Composition
 - What product types?
 - What flight levels, forecast horizons, etc.?
- Graphical Weather Product Size/Fidelity
 - How many pixels per image?
 - How many bits per pixel?
- Compression
 - What are efficient techniques?
 - Should lossy compression be considered? How to determine what is sufficient quality?
- Product Size Variation
 - How much size variation occurs over time due to compression (non-linear effect)?
 - How should corresponding communications system handle variation?



Requirements Summary

Scoring Rqmt Area	Summary Requirements
Ground-to-Air Capacity	High-Fidelity, Comprehensive: 183 kbps Multi-Fidelity, Comprehensive: - regional: 1.3 kbps - CONUS: 38 kbps
Platform Constraints	Appropriate for GA/regional aircraft
Coverage	CONUS and Global
Cost	Under \$5000 NRE; minimum recurring
Spectrum/Deployment	System operational by 2007 and 2015
Link Availability	99%
Latency	5 minutes

- This set used for architecture analysis and scoring



Summary

- FIS requirements analysis focused on capacity
 - Highly variable estimates from different sources
 - Dependent on distribution methodology and other technical parameters
 - Independent effort has sought to provide first-order estimate from "first principles"
- Open research questions remain and are part of current NASA/APL work