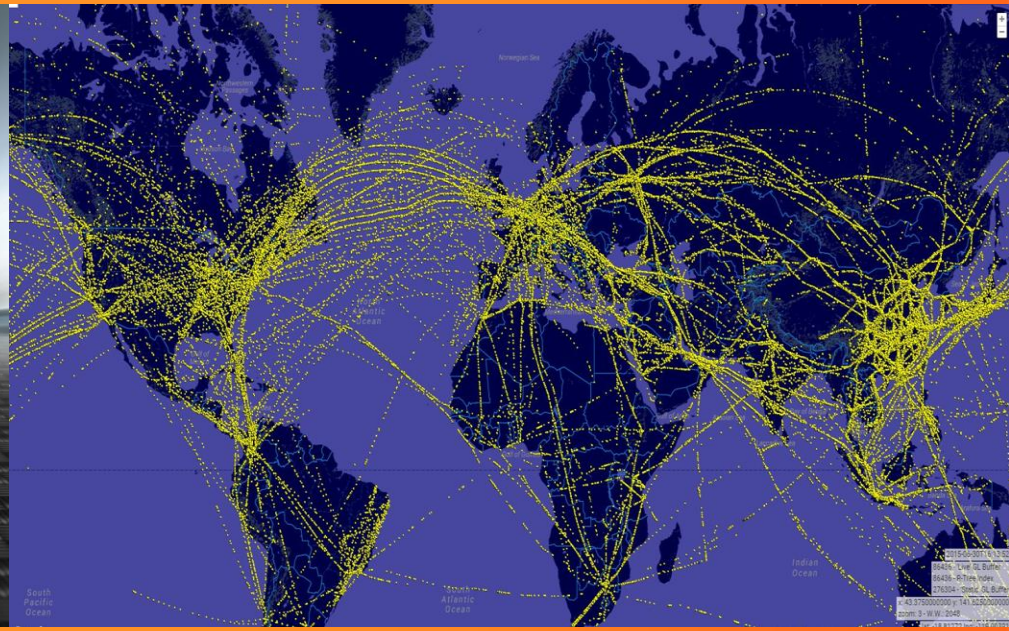

Long Range Communication

Iridium Next and HF Remote

Global Aircraft Tracking - Link Diverse Approach

June, 2018

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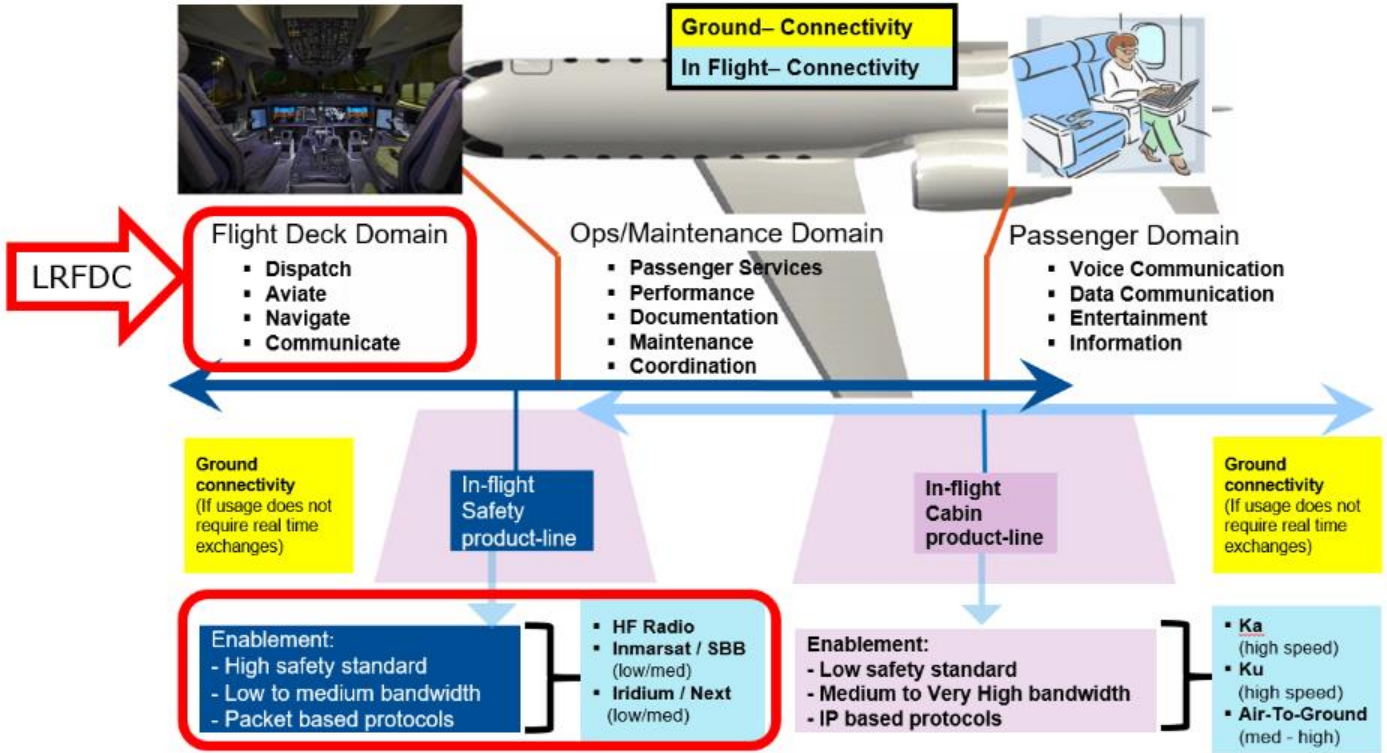
Agenda

- Long range flight deck comm (LRFDC)
- Technology vulnerabilities
- Legacy HF
- New HF Remote (HFR) system
- HFR development roadmap

Aircraft Domains and Use Cases…



…and Technology Choices

- VHF
  - Limited to line-of-sight
  - Good enough voice and data quality
  - Less expensive DoC
- HF
  - Long range, broadcast
  - Poor voice quality
  - Less expensive DoC
  - Maintenance actions difficult
- SATCOM
  - Long range, point to point only
  - Good voice quality
  - Extended data bandwidth
  - More expensive DoC

…Each with Market Inhibitors and Drivers

- Emerging/Growing Datalink Requirements
  - Increased ATC services
  - Aircraft tracking
- Link Diversity
  - Does dual SATCOM present a single point of failure?
  - Will dual SATCOM gain approval to meet LRC required communication performance?
  - Connectivity that is secure and private
  - More data, more often
  - Anonymity – bizav and government/military
  - Autonomy – regional, national, strategic
- Ground Infrastructure
  - There are areas of the world where infrastructure constraints drive interesting technology choices

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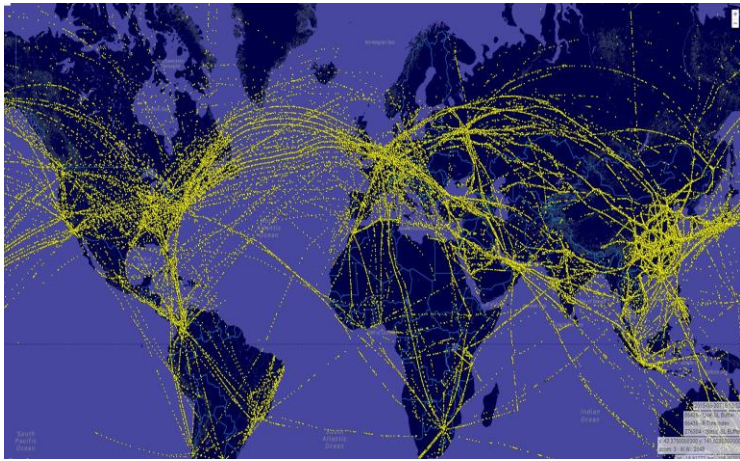
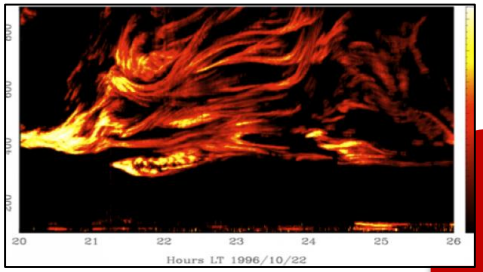
…and Longer-Term Considerations

- Continuous connectivity
  - Coverage anywhere in the world, all the time
- Voice and data capability
  - Both needed; only one mandated outside China
  - Bandwidth to support growing data requirements
- Mandate compliance
  - Aircraft tracking
  - HF Voice
- Cyber security
  - For ATC
  - For Principal
  - For connected aircraft ecosystem
- Proliferation of new systems driven by national autonomy goals

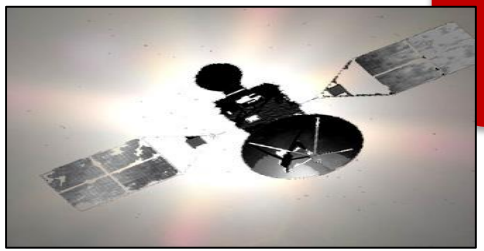


Single comm technology magnifies vulnerabilities…

L Band SATCOM



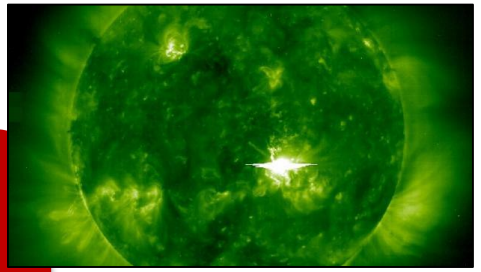
Scintillation



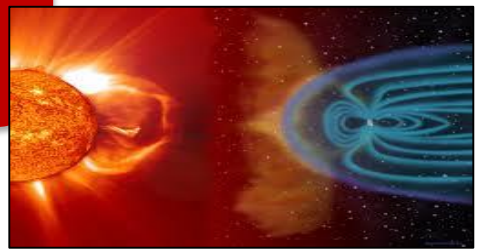
Satellite Outages

Security

HF Terrestrial Comm



Solar Flares



Radiation Storms

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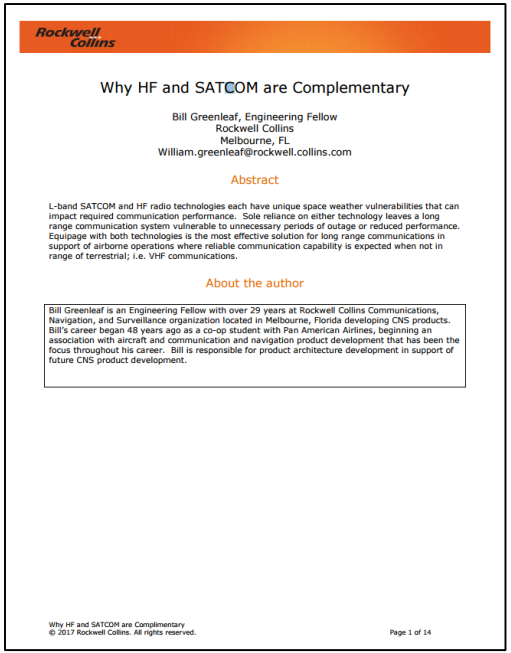
White Paper – Why HF and SATCOM are Complementary

- Voice and Data Needed Everywhere
- Electomagnetic Propagation
  - Impact to HF
  - Impact to SATCOM
- Space Weather and Solar Events
- Information from NOAA
  - Radio Blackout
  - Geomagnetic Storm Impact
  - Solar Storm Effects



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Why HF and SATCOM are Complementary

Bill Greenleaf, Engineering Fellow
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Abstract

L-band SATCOM and HF radio technologies each have unique space weather vulnerabilities that can impact required communication performance. Sole reliance on either technology leaves a long range communication system vulnerable to unnecessary periods of outage or reduced performance. Equipage with both technologies is the most effective solution for long range communications in support of airborne operations where reliable communication capability is expected when not in range of terrestrial; i.e. VHF communications.

About the author

Bill Greenleaf is an Engineering Fellow with over 29 years at Rockwell Collins Communications, Navigation, and Surveillance organization located in Melbourne, Florida developing CNS products. Bill's career began 48 years ago as a co-op student with Pan American Airlines, beginning an association with aircraft and communication and navigation product development that has been the focus throughout his career. Bill is responsible for product architecture development in support of future CNS product development.

https://insights.rockwellcollins.com/2018/02/06/why-hf-and-satcom-are-complementary/

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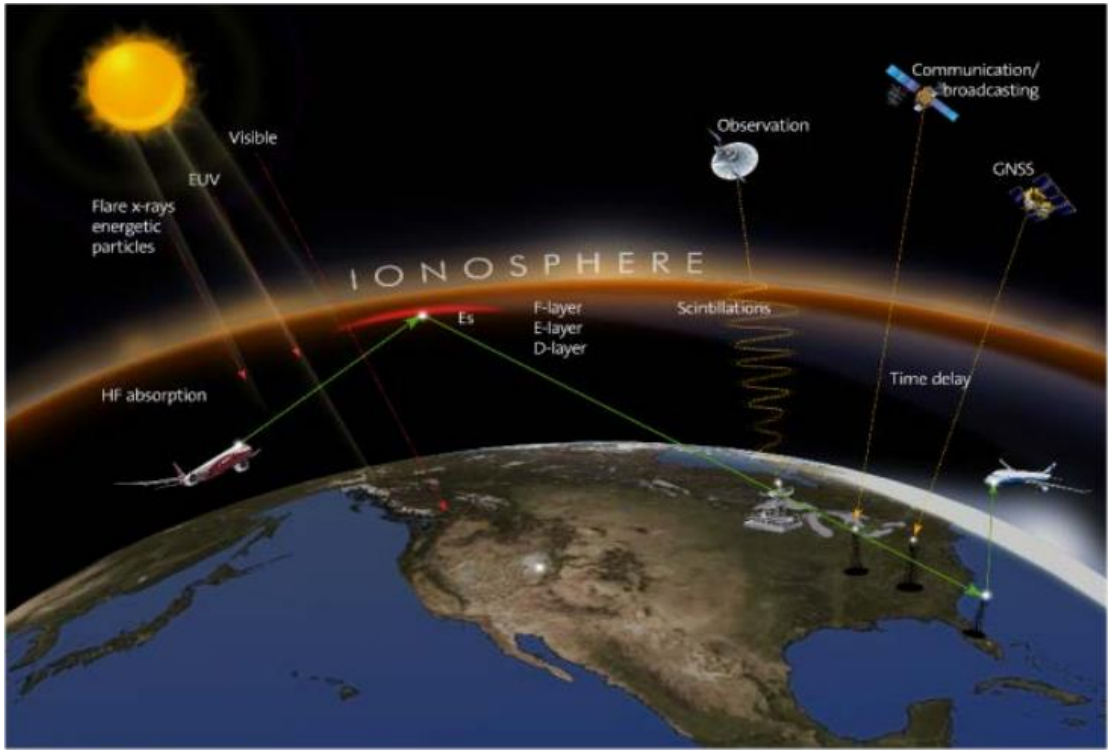
Atmospheric Propagation Effects

- HF - LoS and BLoS Propagation
  - Minimally Effected by Ionosphere
  - More Effected in Troposphere by Space Weather
- L-Band – LoS Propagation
  - Effected by Space Weather in both Ionosphere and Troposphere



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White Paper Summary

- Solar Weather results in various magnetic, radiation, and propagation effects that impact electronic systems
- HF and L-Band SATCOM are impacted by different changes in Ionosphere
  - HF – Effected by D-Layer absorption and F-Layer reflection
  - L-Band – Effected by F-Layer scintillation
- Current operational data shows that L-band SATCOM has been available when HF has difficulties and HF has been available when L-band SATCOM has difficulties

…Link Diversity mitigates technology vulnerabilities

Coverage / Capability / Bandwidth /Cost Analysis: Critical Gaps

	HF	Iridium	Inmarsat
Global Coverage	Yes	Yes	Polar Limitations
Voice and Data Capability	Yes	Yes	Yes
Bandwidth	May Not Support IPS*	Currently Limited	Yes
Acquisition Cost			
Service Cost			

Link Diversity Analysis: Critical Gaps

	HF	Iridium	Inmarsat
HF	No	Yes	Yes
Iridium	Yes	No	No Spectral Diversity
Inmarsat	Yes	No Spectral Diversity	No

*Internet Protocol

Future HF Remote (HFR) Transceiver

+

Conclusion: SATCOM – only equipment is inadequate

…about that HF performance…

HF systems have not substantially improved in many decades

Current HF deficits

- Voice quality – market expects SATCOM clarity that analog HF does not deliver
- Datalink
  - Availability: slow, unreliable, disconnects
  - Data rate: not sufficient to support ATC/AOC needs
- Size – bulky, multiple LRUs, excessive cabling, production impact
- Weight – problem for long range aircraft performance
- Pilot workload - cumbersome

New Generation HF

- Remote mounted integrated transceiver
  - 4 MCU, mounted at coupler location
- XCVR location near antenna minimizes RF loss and impact of heavy coax cables
  - Transmit output power can be lower – integrated unit does not have to make up for coax losses
  - Units can be smaller and lighter using modern design standards
- Voice communication transition to data packets similar to our current IP telephones
- Advanced SDR features enable simultaneous voice and data

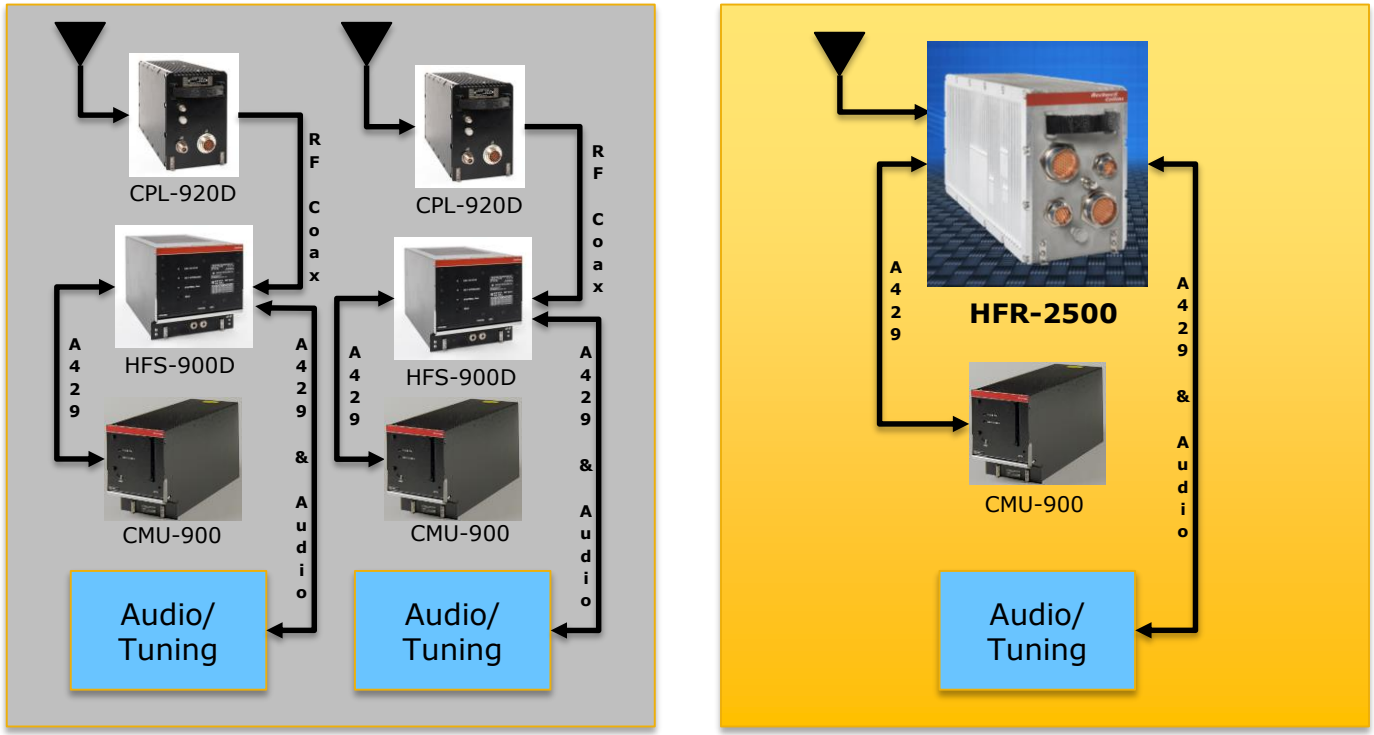
Current HF System
(Providing Dual HF Capability)

Future HFR
(Providing Dual HF Capability)

Key Benefits

- Significant weight reduction (>90 lbs)
- Significant Volume reduction (>80%)
- Eased installation - eliminates Fiber Optic interface, simplifies cable runs

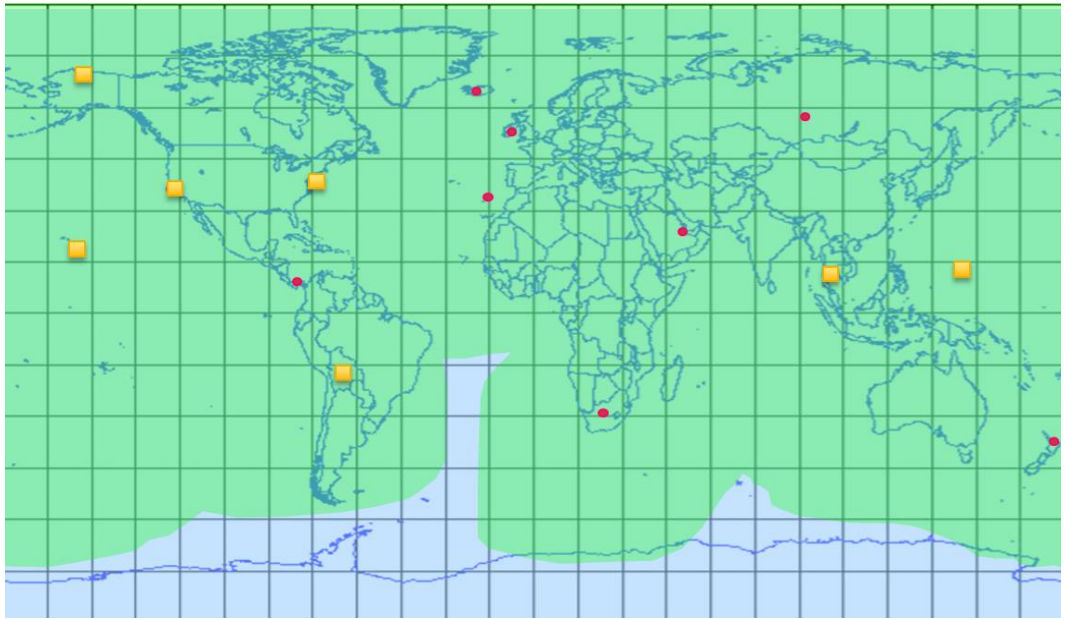
HF System Block Diagram Comparison



Ground stations already in place worldwide

HF Ground Stations

- Alaska
- Bahrain
- Bolivia
- California
- Canary Islands
- Guam
- Hawaii
- Iceland
- Ireland
- New York
- New Zealand
- Panama
- Russia
- South Africa
- Thailand



Legend
HFDL station
Voice/HFDL station

Areas of Primary coverage

Areas of Secondary coverage

- 16 ground stations collocated at existing sites
  - Transmitters
  - RX & TX antennas
  - Shelters
  - GS computers
  - Routers
- Updated software protocol
  - Integrated voice/data
  - Enables worldwide voice
  - Supports RCP-240 (FANS)

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HFR Summary

- Modernization of HF communications
  - Quality (voice clarity, link availability)
  - Multifunctional/multi channel
  - Higher data rate (100+ kpbs)
  - SWaP reductions
- LRC link diversity
  - HF and SATCOM complementary for best solution (coverage & reliability)

- Value for your fleet
  - ✓ Link diversity for aircraft dispatch ability
  - ✓ Reduced operating cost
  - ✓ Optional advanced features increase mission capability
  - ✓ Reduced size, weight and power requirements
  - ✓ Ease of installation – operation - maintenance

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