GRAPHICAL COCKPIT-BASED DEPICTIONS OF SPACE VEHICLE OPERATIONS

BASED UPON USE OF AERONAUTICAL INFORMATION SERVICES DATA LINKS

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FAA's Next Generation Air Transportation System (NextGen)

- **To facilitate a more efficient use of domestic and oceanic airspace while maintaining the current level of safety for the public, the FAA is researching new technologies and capabilities that would speed the flow of flight critical information to necessary user recipients**
  - **Data Links**
    - **Automatic Dependent Surveillance-Broadcast (ADS-B)**
    - **Aeronautical Information Services (AIS)**
    - **Flight Information Services (FIS)**
  - **Recipients**
    - **Air traffic control**
    - **Airline operational control**
    - **Pilots**

What is AIS DL?

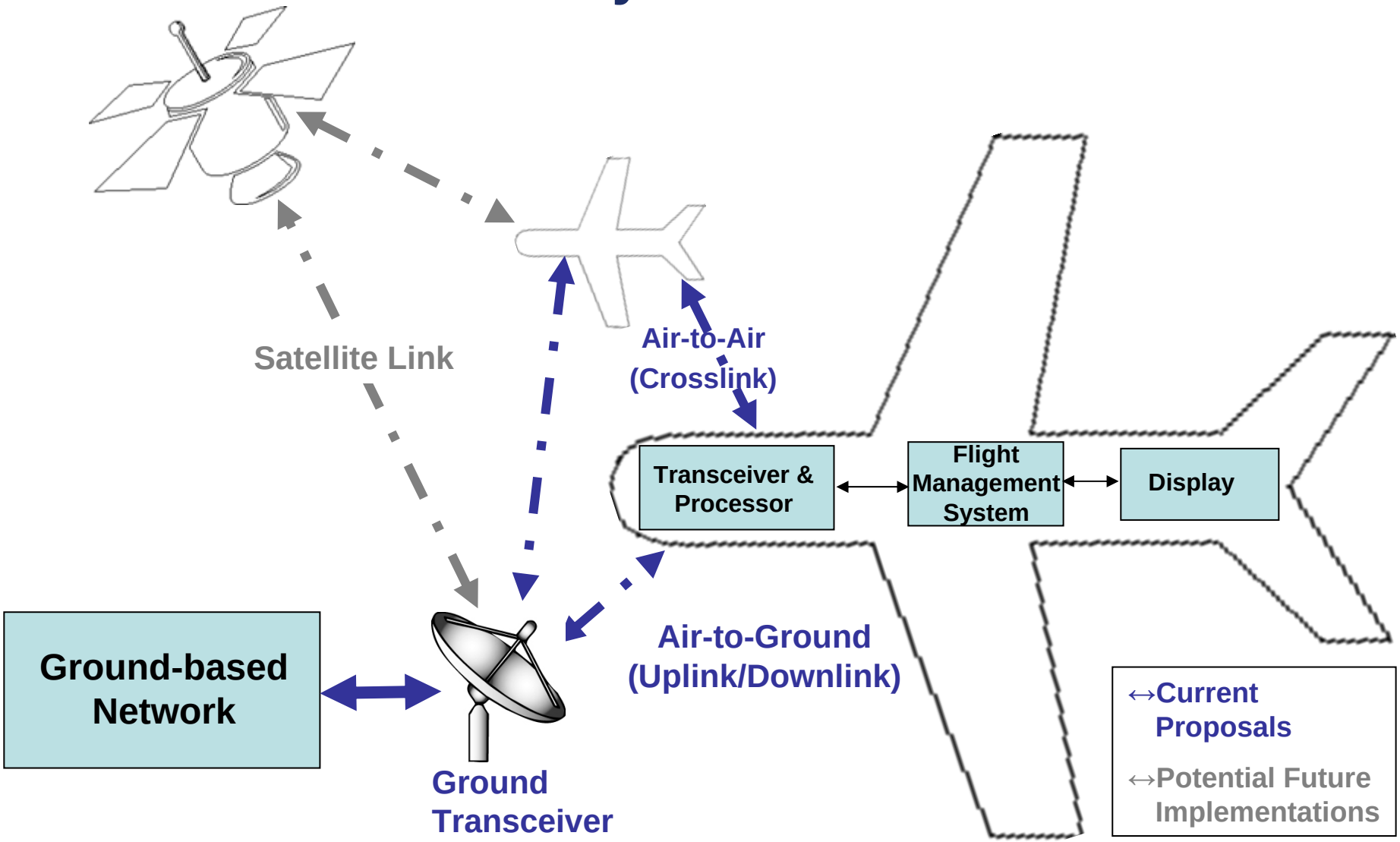
- Aeronautical information services data link (AIS DL) is a system designed to collect and distribute meteorological, flight plan, and NOTAM data to air traffic facilities and airspace users

- Enable exchange of data from:
  - Ground-to-air
  - Air-to-ground
  - Air-to-air

- Data received onboard an aircraft can be processed and displayed in the cockpit using certified as well as commercial off the shelf (COTS) devices
  - Cockpit display of traffic information (CDTI)
  - Multifunctional displays (MFDs)

Example Cockpit Graphical Display

Basic Data Link System Level Architecture



Example: Air-to-Air and Air-to-Ground Meteorological Data Exchange

- **ConOps being developed in collaboration with Swedish Civil Aviation Administration (LVF)**
- **Candidate applications make use of either crosslink and downlink MET data link services**

– **Crosslink MET Applications may enhance:**
  - ADS-B enabled, CDTI Assisted Visual Spacing (CAVS)
  - ADS-B enabled, Continuous Descent Arrivals (CDAs)
  - ADS-B enabled, oceanic in-trail procedures
  - ADS-B enabled, wake vortex modeling / visualization
  - Real-time turbulence detection and reporting
  - Enhanced FMS performance
  - Runway braking action

– **Downlink Applications may enhance:**
  - En route ATC trajectory prediction and scheduling
  - Enhanced aviation weather forecasts, including graphical turbulence plot forecasts
  - Enhanced FMS performance (uplinked [ground-to-aircraft], processed data)
  - Enhanced local and regional public forecasts
  - GNSS (geometric) and baro altimetry correlation application
  - ADS-B enabled, Flight Deck-Based Merging and Spacing (FDMS)

Candidate Future AIS Products

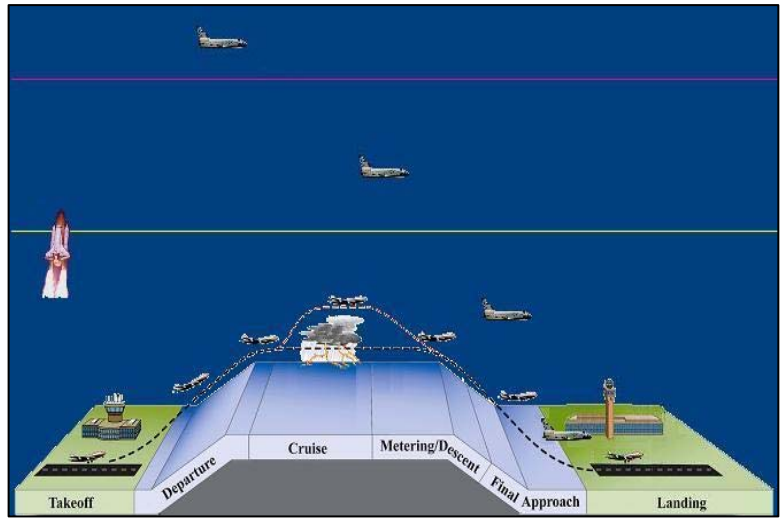
- **FAA is currently supporting the RTCA SC-206/EUROCAE WG-76 standards development by identifying candidate graphical AIS products such as:**

1. GPS / WAAS Outage NOTAMs
   - Provide flight crews with notices of global positioning system / wide area augmentation system outages, accuracy issues, etc.
2. Environmental NOTAMs
   - Provide enhanced situational awareness to assist flight crews in the recognition and avoidance of environmentally sensitive airspace
3. Temporary Flight Restriction (TFR) Notification
4. Special Use Airspace (SUA) Status
5. Closed Runway / Taxiway Depictions
6. **Commercial Space Vehicle NOTAMs**
   - Provide fight crews with graphical depictions of:
     - Planned and actual space vehicle trajectory data during routine operations
     - Predicted space debris hazard areas if a vehicle were to fail during launch or reentry
     - Estimated airspace containing hazardous debris in the event of a launch or reentry accident

Hazards to Aircraft from Space Vehicle Ops

1. The Collision Hazard

   During launch and reentry, space vehicles and aircraft will fly through the same airspace



2. The Debris Hazard

   In-flight failure of the space vehicle generates falling debris. Impact with a fragment weighing as little as one gram can inflict considerable damage on an aircraft

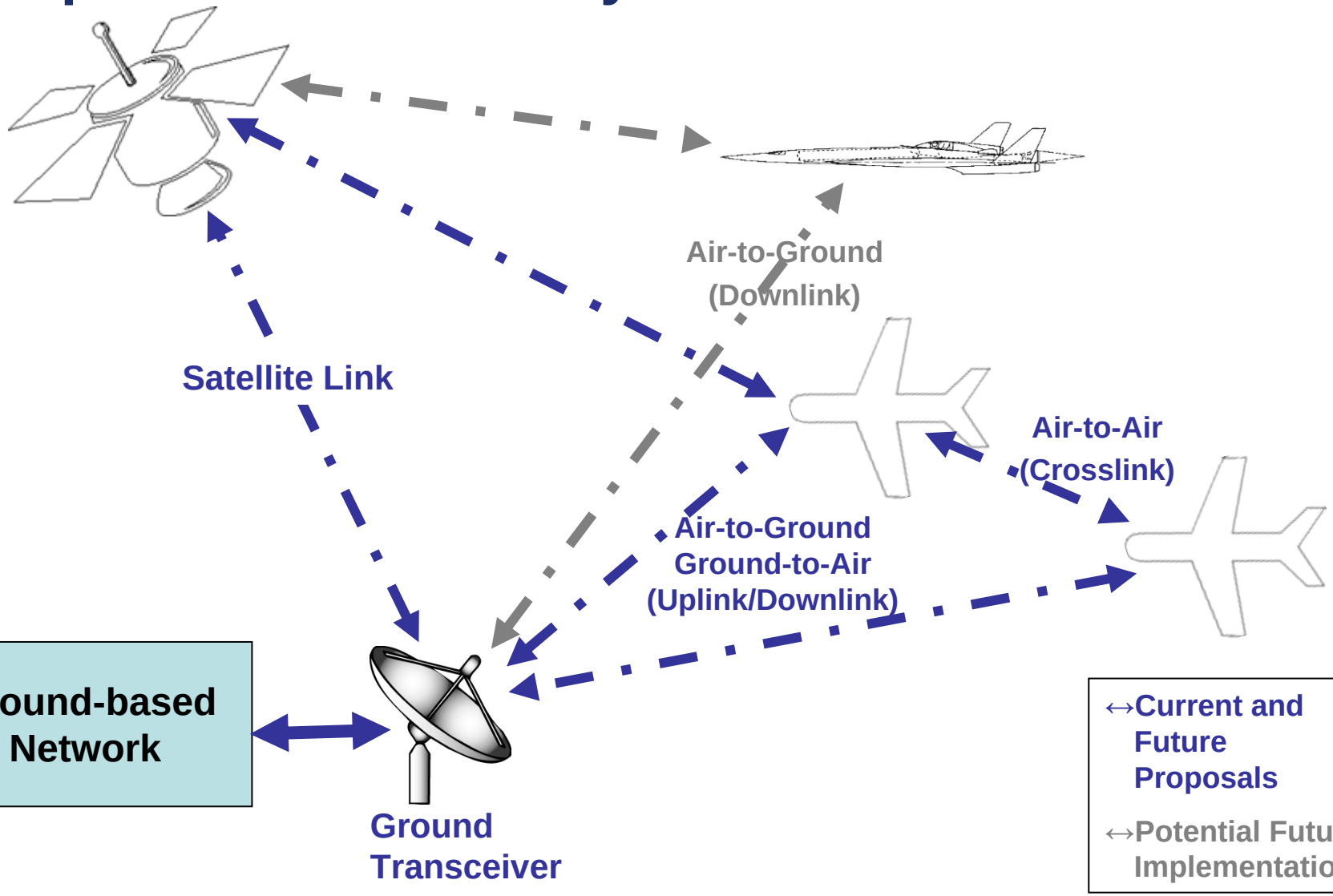
Proposed AIS Space Vehicle Application

- **Nominal operations**
  - Ground-based system publishes planned space vehicle trajectory
  - Space vehicle downlinks actual trajectory state data
  - Ground-based system receives space vehicle data
  - Ground-based system computes and broadcasts AIS NOTAM containing predicted debris hazard areas
  - Equipped aircraft receive broadcast space vehicle trajectory data and predicted debris hazard areas from ground and graphically display them onboard
    - Receipt and display of space vehicle trajectory data could help mitigate risk of collision w/ space vehicle
    - Receipt and display of predicted debris hazard area could help mitigate risk of aircraft impact with falling debris, allowing aircraft to plan to avoid these areas

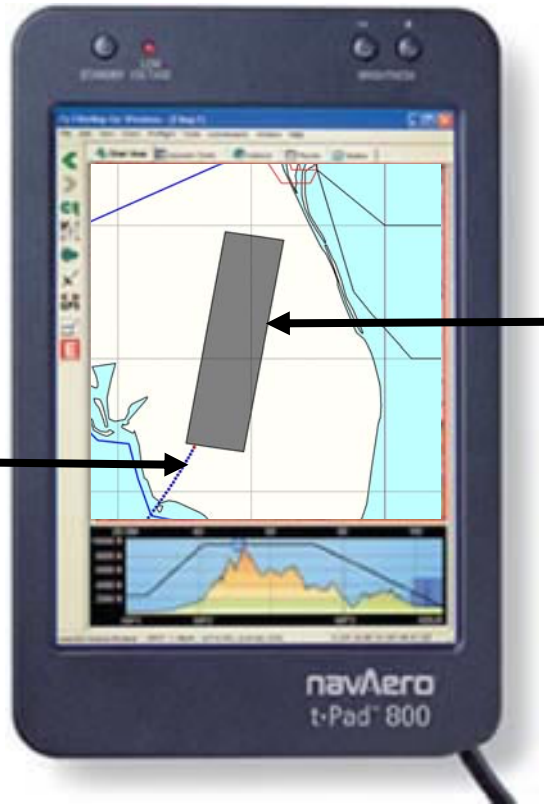
Proposed AIS Space Vehicle Application

- **In the event of a space vehicle failure that produces falling debris**
  - Ground-based system computes and broadcasts AIS NOTAM containing estimated debris hazard area
  - Equipped aircraft receive AIS NOTAM from ground and graphically display hazard area boundary onboard
    - Receipt and graphical display of estimated debris hazard area could help mitigate risk of aircraft impact with falling debris, providing information to allow aircraft to effectively maneuver to avoid these areas

Updated Data Link System Level Architecture



Example Cockpit Graphical Display



Predicted or actual debris hazard area

Actual trajectory

Enhanced AIS Space Vehicle Application

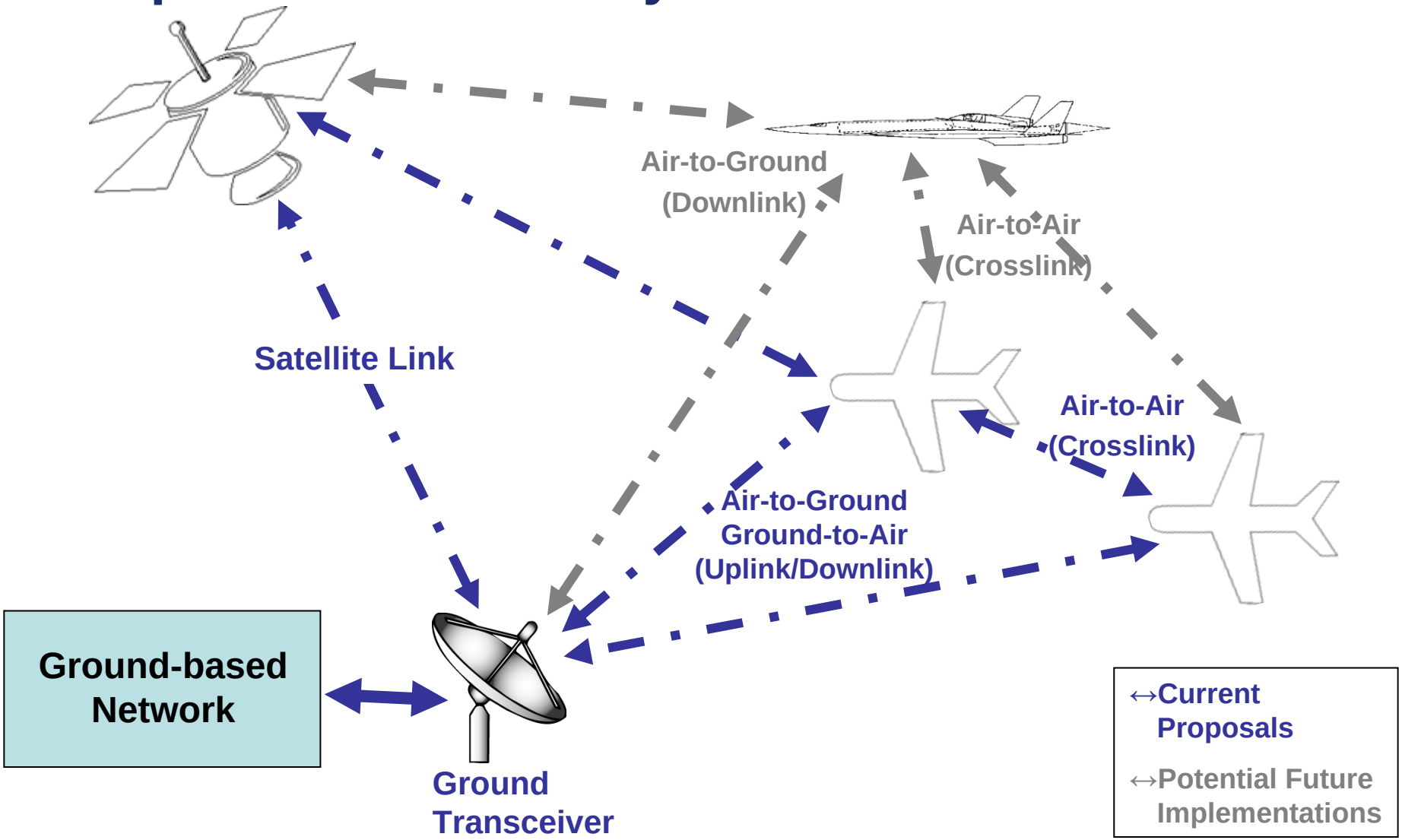
- Space vehicle broadcasts actual trajectory state data

- Equipped aircraft receive broadcast space vehicle trajectory data and predicted debris hazard areas from space vehicle and graphically display them onboard
  - Decrease in data latency with corresponding increase in time available to react

- Ground-based system still computes and broadcasts AIS NOTAM containing predicted debris hazard areas

- In the event of a space vehicle failure, ground-based system still computes and broadcasts AIS NOTAM containing estimated debris hazard area

Optimal Data Link System Level Architecture



How Would AIS-DL Fit Into Space and Air Traffic Management ConOps?

- **FAA is currently developing ground-based space and air traffic management tools**
  - Provides situational awareness, decision support to ATC during space vehicle operations within and above the NAS
  - ATC uses information collected in ground-based systems to provide verbal direction to aircraft, as necessary, to mitigate risks
- **Ground-based system may not be capable of mitigating foreseeable risks to some aircraft**
  - General aviation (VFR) aircraft flying in or near hazarded airspace are generally not under direct air traffic control (e.g., no radar, no voice communications).
  - Uncertainty in location of aircraft flying in non-radar controlled environments (e.g., oceanic)
  - Substantial communications lag between ATC and traffic flying in non-radar controlled environments

How Would AIS-DL Fit Into Space and Air Traffic Management ConOps?

- **AIS-DL provides means to approach problem from both directions**
  - ADS-B DL has been identified as a potential enabling technology for transmitting space vehicle state data to ground-based systems (air-to-ground link)
  - AIS DL has been identified as a potential enabling technology for transmitting ground-computed data to the cockpit (ground-to-air link)
- **AIS-DL provides the potential for cockpit-based risk mitigation**
  - Air-to-air and ground-to-air transmission of timely data provides cockpit situational awareness and decision support tools to VFR and IFR flight operations, globally

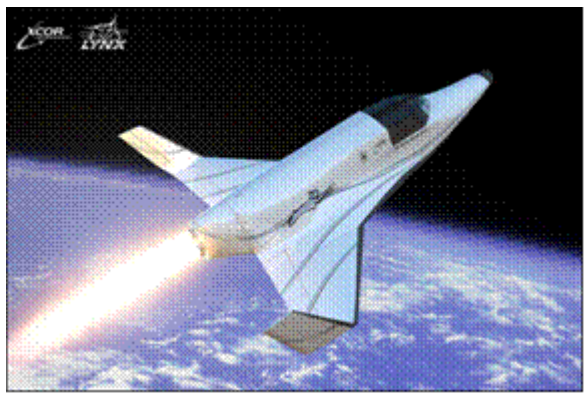
Why is this Important Now?

- **AIS DL and ADS-B are enabling technologies of NextGen**
  - Key elements of “network enabled operations” (NEO)
  - The FAA’s ADS-B implementation schedule calls for full equipage of ADS-B “out” of most aircraft by 2020
  - Current ADS-B message standards already include a message element identifying target as a space vehicle.
  - “Seamless integration” of space and air traffic operations will require these and other technologies

- **SC-206 / WG-76 moving ahead with standards definition efforts**
  - Space vehicle application will aid committee in defining performance and requirements for applicable data link services
  - Failure to include space vehicle element could result in technology advancement without consideration of space transportation applications

Why is this Important Now?

- **ADS-B technology is already in use**
  - Aviation Communication and Surveillance System's (ACSS) *SafeRoute* ADS-B enabled navigation tools
    - Obtained FAA certification in November 2007
    - Currently in use in a pilot program with United Parcel Service (UPS) at its international air cargo hub in Louisville, KY
    - Contains a displayable, currently unutilized aircraft message category for a space/trans-atmospheric vehicle (SPCV)
- **Frequency and impact of commercial space operations could dramatically increase within the next year**



Courtesy XCOR Aerospace

Courtesy Virgin Galactic

Challenges

- **Contingency procedures for aircraft flight crews will need to be developed and coordinated internationally**
  - Flight crew coordination with ATC, where available
  - Moving aircraft without proper planning could increase risks
    - Flight operations along busy North Atlantic Track System will require careful analysis and discussion before suitable procedures can be developed for a “mass turn back” procedure

- **Technical limitations may exist**
  - Weight penalty of added equipment on space craft
  - Data rates, data integrity, antenna placement, plasma interference…

Potential Next Steps

- **Assist SC-206 / WG-76 in development of:**
  - **Operational Service & Environment Definition (OSED)**
    - **Identify expected benefits, anticipated constraints, and associated human factors**
    - **Identify and define message set elements**
    - **Define operating methods, data integrity/exception handling, service time (data latency) constraints**
  - **Safety and Performance Requirements (SPR)**
    - **Establish operational (safety, capability, and performance) criteria based on intended operations**
  - **Interoperability Requirements (INTEROP)**
- **Identify potential R&D to address technical challenges**
- **Inclusion in FAA NextGen Work Plan**

Backup Slides

What is RTCA?

- **Private, not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance, and air traffic management (CNS/ATM) system issues**

- **Functions as a Federal Advisory Committee to the FAA**
  - FAA uses recommendations as basis for policy, program, and regulatory decisions and by the private sector as the basis for development, investment and other business decisions

- **Volunteer special committees hold public meetings to develop consensus-based recommendations**

- **http://www.rtca.org/**

What is EUROCAE?

- European Organization for Civil Aviation Equipment
- A non-profit organization whose primary objective is the development of standards performance specifications and guidance documents for Civil Aviation Equipment to be adopted as regulatory documents by Authorities
- Operates in the frame of Working Groups tasked to develop documents through consensus
- Works in close cooperation with American counterparts (RTCA, SAE, ARINC)
- http://www.eurocae.eu/

RTCA's SC-206 / EUROCAE's WG-76

- **RTCA's Special Committee (SC) 206 established February 2005 at request of FAA**

- **FAA plans to provide data link transmissions of meteorological (MET) and aeronautical information (AIS) through:**
  - Universal Access Transceiver (UAT) ground stations (ground-to-air)
  - Dedicated Controller / Pilot Data Link
    - Automatic Dependent Surveillance-Broadcast (ADS-B) data link can be used to provide aircraft-to-ground and aircraft-to-aircraft data

- **To accomplish these goals, the joint RTCA SC-206 / EUROCAE WG-76 committee is tasked to develop:**
  - Operational Service and Environment Definition (OSED) document
  - Safety and Performance Requirements (SPR) and Interoperability Requirements (INTEROP) documents
  - Minimum Aviation System Performance Standards (MASPS)