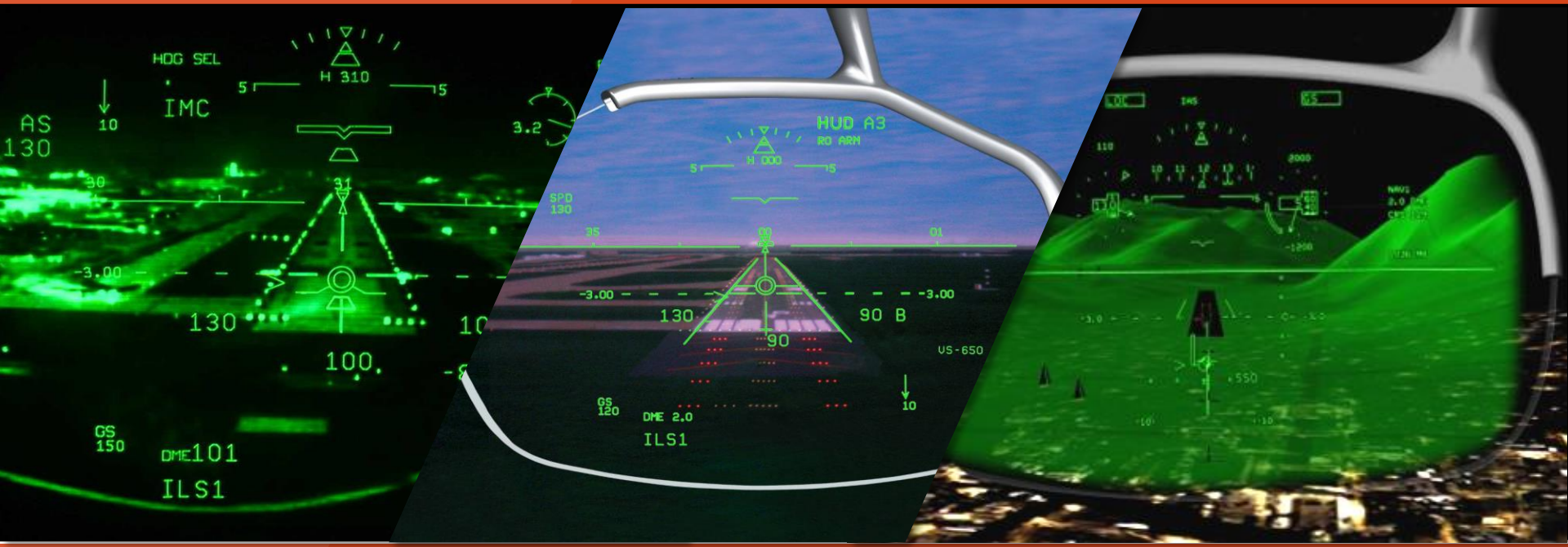


Head-up Guidance & Vision Technologies

Enabling Safer and More Efficient Airline Operations

March, 2017

Rockwell Collins

Building trust every day

Agenda

> HGS Introduction

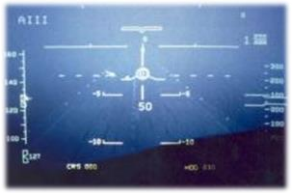
> HGS Value – Safety & Economics

> Vision Systems – a view to the future

> Worldwide Adoption

What is HGS? – A Quick Introduction

- **HGS™ = Head-up Guidance System**
  - Rockwell Collins' Head-Up Display exclusive for aviation
  - First introduced in commercial aviation in the mid-1980's



- Presents critical flight information and guidance as pilots look outside
  - Flight path
  - Energy
  - Altitude
  - Patented guidance
  - Unique flight safety features

Aviation Safety Considerations

- 3% of approaches worldwide remain "unstable"

  Flight Safety Foundation

- Runway excursions, tailstrikes, and hard landings are costly, yet preventable

- Industry recognizes pilot manual flying skills are weakening – FAA SAFO

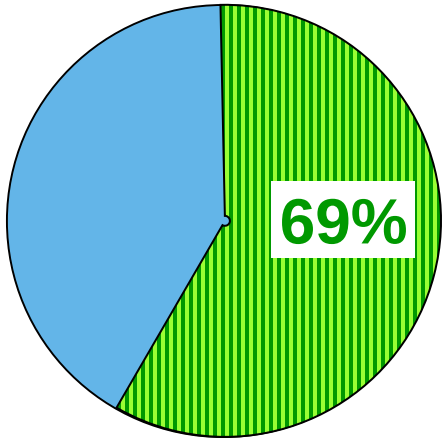
- Go-Around execution is still are not to the level of proficiency to meet operational and regulatory compliance – FAA SAFO

What does one major tailstrike cost?

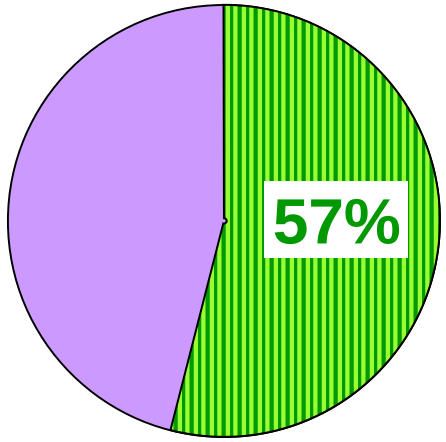
Safety Benefits of HGS Technology

HGS would have highly likely or likely prevented

Takeoff & Landing



Loss of Control



HGS Provides Optimum Go-Around Guidance and Precision

Key Go-Around symbology – Flight Path, Boresight, Pitch Target, Energy Caret, Airspeed/Speed Error Tape, at fifty feet transition to Flight Director Cue

Typical Nighttime Approach at Unimproved Airport

Typical Nighttime Approach at Unimproved Airport w/HGS

HGS/HUD Optimizes Stabilized Approach - Flight Path Group

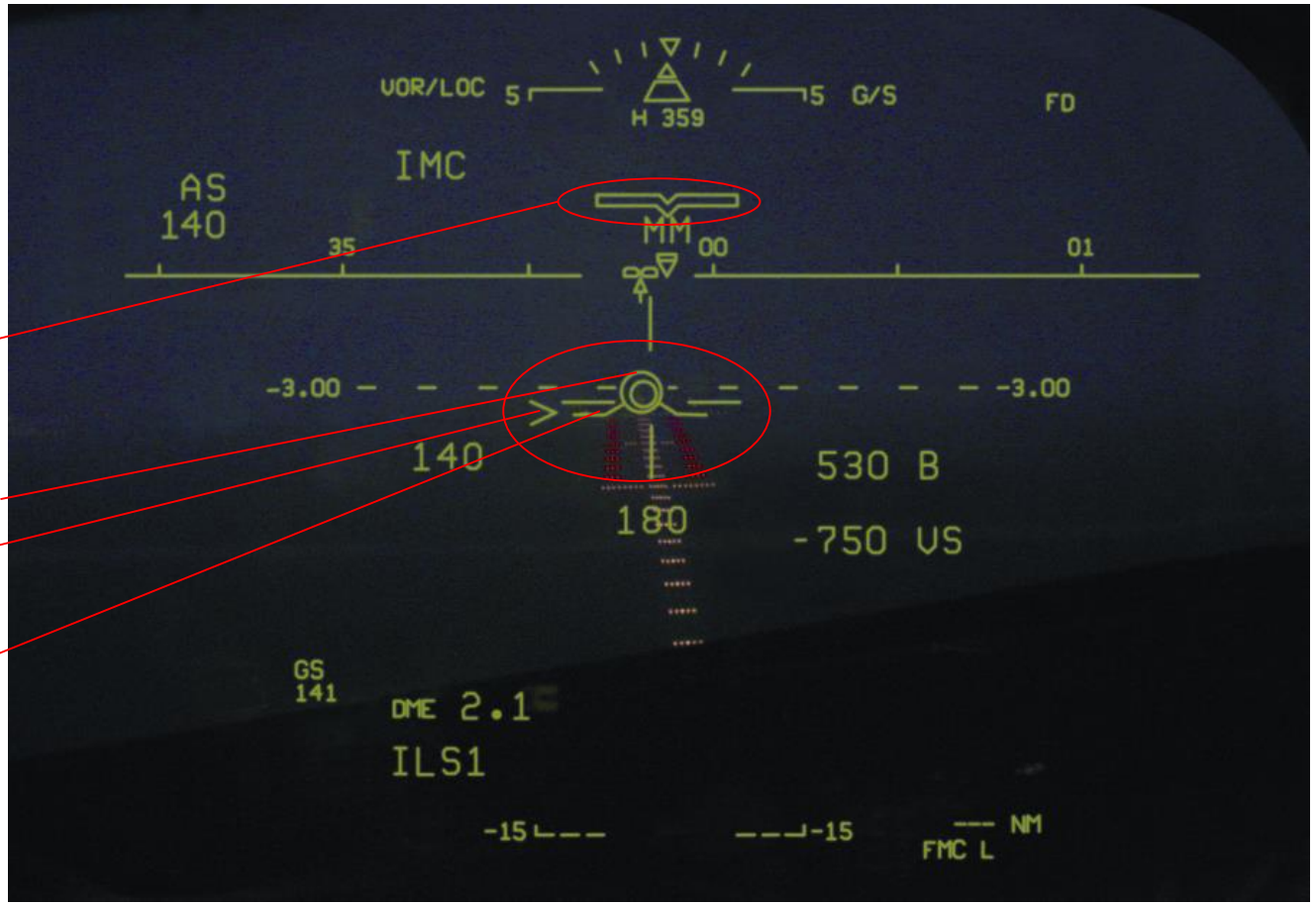
The flight path group of symbols are the heart of creating a stabilized approach.

Boresight

FPV Flight Path Vector

Inertia Caret

Speed Error Tape



By using the inertially derived flight path, the HGS symbology shows flight path information to the pilot that is *conformal* with the real world. In other words, what the pilot sees in the HGS is what they can expect to see “outside” the aircraft; the pilot’s eyes will already be focused on the landing runway aim point before the runway is in view.

HGS Rollout Information

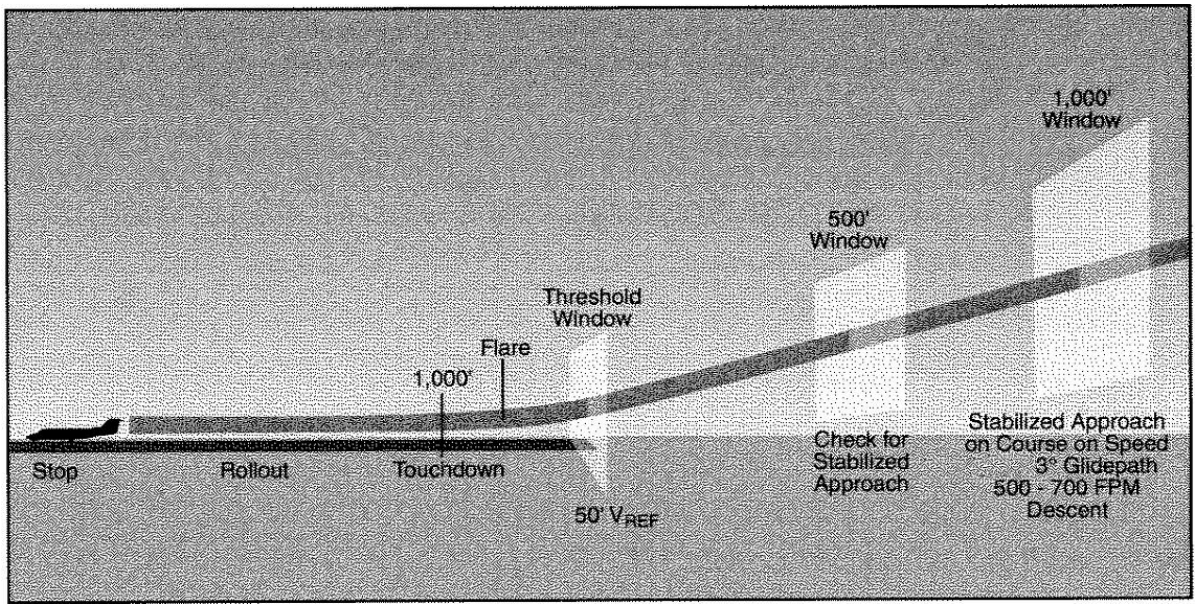
The HGS provides consistent speed, deceleration, runway remaining information to the pilot. In addition the deceleration brake index markings correlate to the autobrake settings and when used with runway remaining provides the pilot with real time braking efficiency information.

HGS Provides Means to Avoid Runway Excursion

- Risks associated with runway overruns during landing phase of flight
  - Hazards associated with runway overruns (EASA, FAA, NTSB)
    - Non-stabilized approach
      - Too high on approach (steep)
      - Tailwind
      - Incorrect decision to land
    - Excess airspeed (high touchdown speed)
    - Landing beyond touchdown point (long landing)
    - Failure to assess required landing distance
      - Wet/contaminated runway
      - Late/incorrect use of brakes
      - Late/incorrect use of reverse thrust
      - Aquaplaning

FAA AC 91-79 (Stabilized Approach)

Landing Configuration
- Landing gear down
- Landing flaps selected
- Trim set
- Fuel balanced
- Landing checklist completed



Stabilized on Profile
- IMC – at 1000 feet above TDZE
- VMC – at 500 feet above TDZE
- Proper landing configuration
- Correct lateral track
- Correct vertical track
- Optimum 3 degree glide path (greater than 3 degrees are “special cases”)
- Airspeed within acceptable range

Descent Rate
- Optimum – 500 to 700 fpm
- Not exceed 1000 fpm

Indicated Airspeed
- Not more than Vref+5 with adjustment for wind and other factors
- Never less than Vref

Go-Around should be executed at any time approach is determined to be unstable

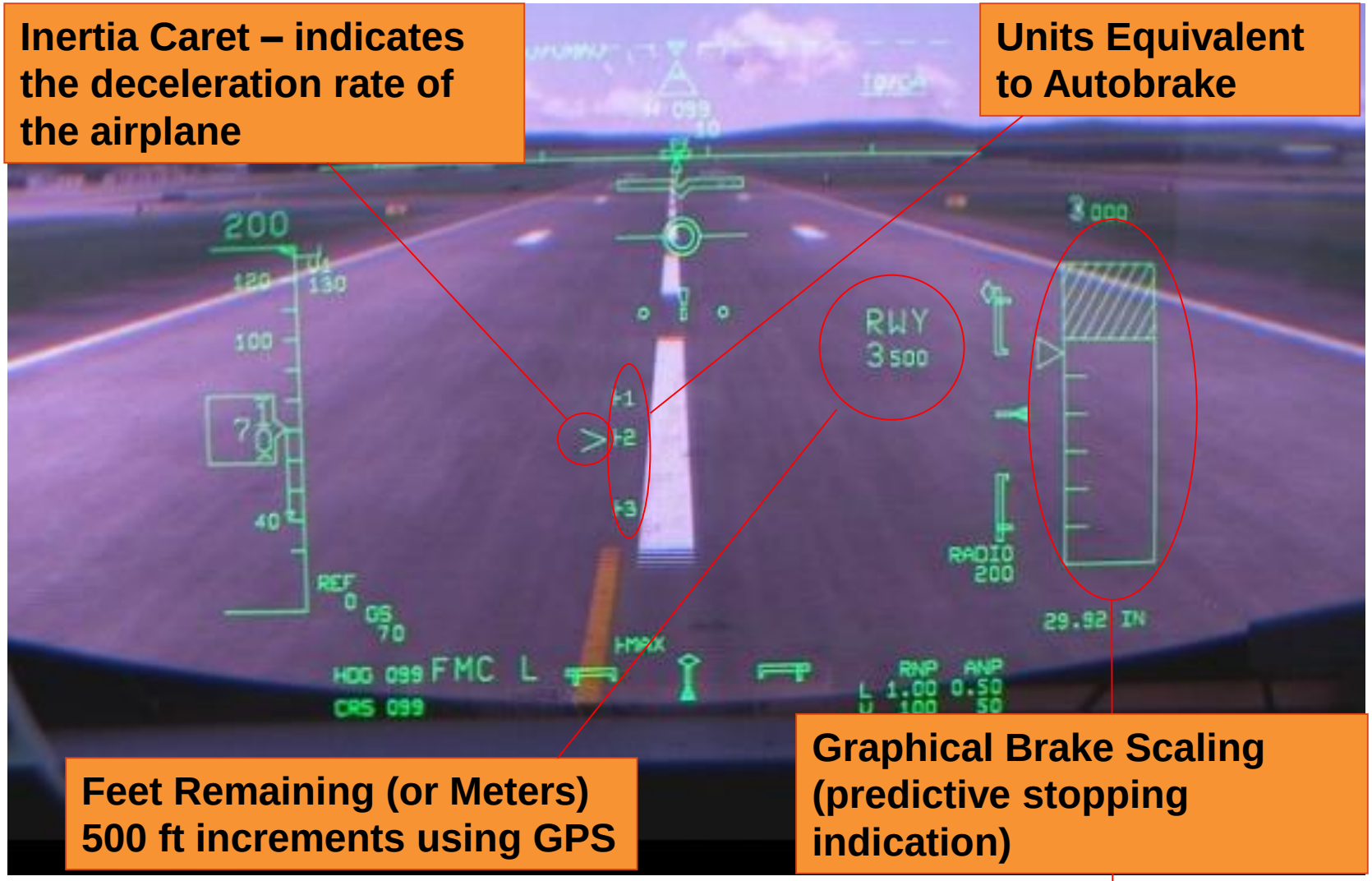
FAA AC 91-79 (Landing Distance Calculations)

TABLE 2. "RULE OF THUMB" ON LANDING DISTANCE CALCULATIONS

Condition	Possible Effect on Landing Distance
Non-stabilized Approach	Unpredictable
Excess Airspeed	
Dry Runway	Additional 300 feet per 10 knots
Wet Runway	Additional 500 feet per 10 knots
Extended Flare (Floating)	Additional 2500 feet per 10 knots
Normal Airspeed	
Negative Runway Slope	Additional 10 percent of landing distance per 1 percent downhill slope
Delayed Touchdown	Additional 230 feet per second (fps)
Excessive TCH	Additional 200 feet per 10 feet above TCH
Delayed Braking	Additional 220 fps

NOTE: These rules of thumb are compiled from the textual material presented in FAA-H-8083-3A. The values contained in Table 2 are not intended to replace data provided by either the manufacturer or the company to perform calculations with the accuracy required for certification or FAA approval. They are intended as a quick reference for pilots making a landing or go-around decision based on previously calculated landing distances. A practical application of these values is shown in Table 3, Sample Landing Distance Worksheet for Part 91 Operations.

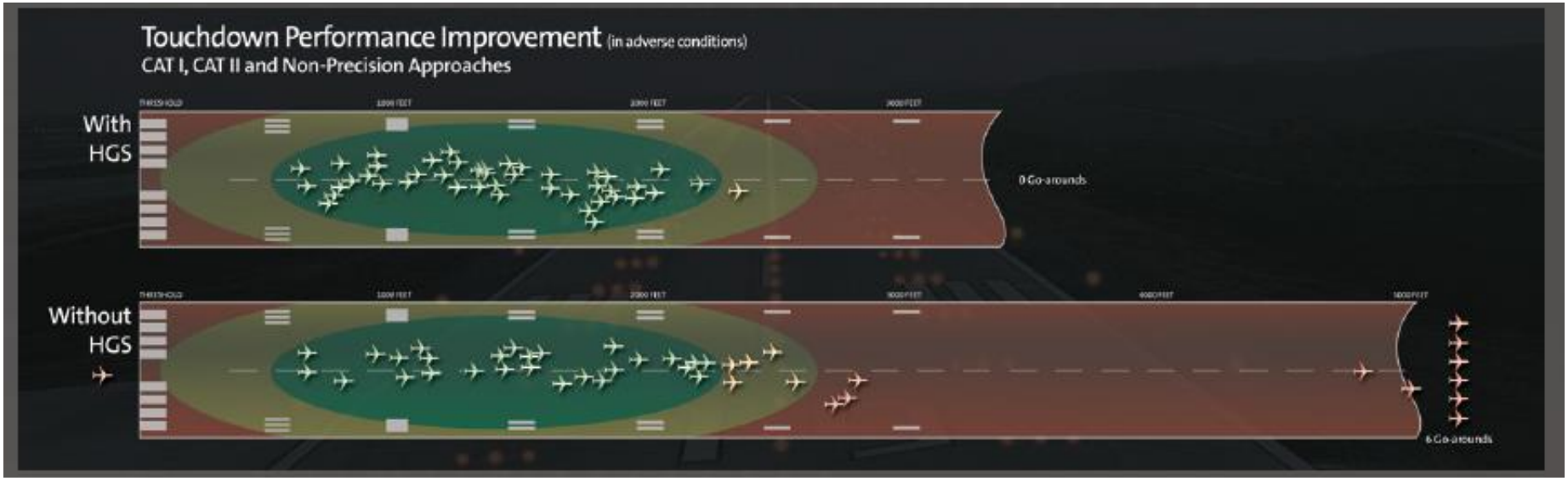
Increased Stopping Awareness



HGS 4000 and HGS 6000 Dual Configuration

Additional Safety Benefits

- Tailstrike Avoidance
- Guidance during emergencies:
  - Engine out, windshear, unusual attitude
- Stabilized approaches, preventing runway excursions
  - Dynamic runway remaining information
  - Consistent landing position



Economics of HGS - Airlines

- Civil Aviation Authorities allow exclusive operations for HGS

Examples:

Flight Phase	Runway ILS	Airport Visibility	Aircraft without HGS	Aircraft with HGS
Landing	Category I	600m	Can Land	Can Land
Landing	Category I	350m	Cannot Land	Can Land
Takeoff	Category I	200m	Cannot Takeoff	Can Takeoff

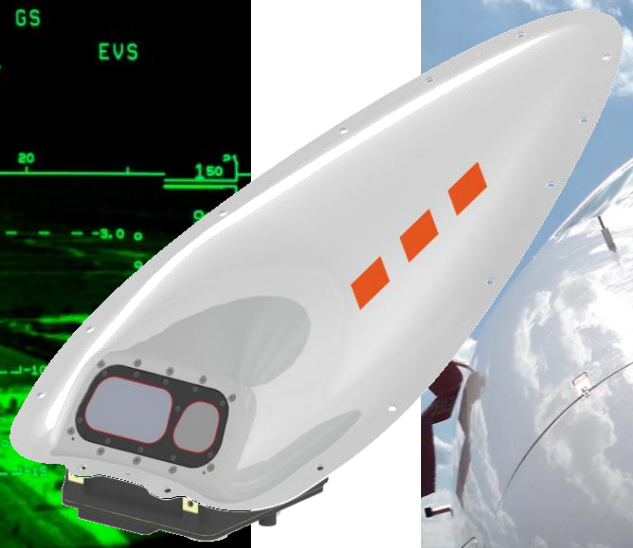
- With HGS fewer flights are disrupted, resulting in:
  - Lower fuel costs
  - Fewer delays/cancellations
  - Increased customer loyalty/revenue

A view to the future

VISION SYSTEMS

Enhanced Flight Vision System (EFVS)

- Enhanced Vision Sensor generates a real-world video image of scene ahead displayed on a HUD
- System utilizes at least one sensor, usually positioned in the airplane radome



EVS-3000 Flight Test Video

Current Flight Operational Capability Gaps

- How do you get passengers here at night?

- What happens if you can land, but you cannot taxi?

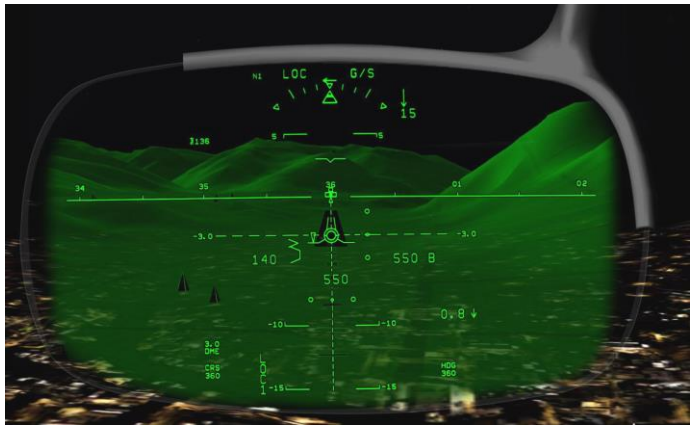
- Runway incursions remain a problem.

EFVS Value Proposition

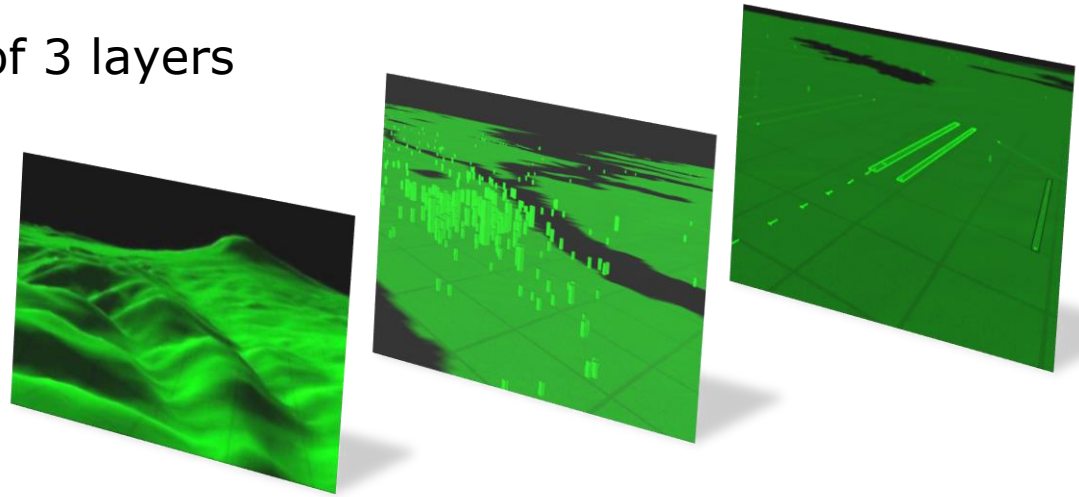
- Taxi / land / takeoff in low visibility at any airport
  - Ground equipment not required
- Prevent dangerous operations resulting from losing awareness
  - Collisions with vehicles, people, animals, etc
  - Runway incursions
- Potential to open airports for nighttime operations
  - Regional airports that lack runway/taxiway lights
  - Increase fleet utilization rates for regional aircraft
- Maintain flight schedules in smoke/haze/dust and some fog

Synthetic Vision System (SVS) on HGS

- Computer generated world view from pilot's perspective



- SVS database consists of 3 layers
  - Terrain
  - Obstacle
  - Airports & Runways



Head-up Combined Vision

ADOPTION WORLDWIDE

Aircraft Manufacturers Support HGS Technology

- Head-Up Displays are now offered on all next generation aircraft, either as baseline or option

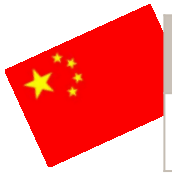
- Rockwell Collins HGS is the most trusted and widely adopted Head-Up Display in aviation
  - Over 7,000 HGS delivered
  - Selected by the worlds most recognized aircraft manufacturers

BOEING
EMBRAER
BOMBARDIER
AVIC
LOCKHEED MARTIN
Beechcraft
Gulfstream
A GENERAL DYNAMICS COMPANY
SAAB
DASSAULT AVIATION
AleniaAeronautica
A Finmeccanica Company

Aviation Authorities Support HGS Technology

- Civil aviation authorities recognize HGS operational and safety impacts
  - Exclusive operational capabilities granted for HGS operators

  - China will require all in-country aircraft to equip with HUD by 2025



China HUD Roadmap	2015	2020	2025
HUD Equipage Requirement	10%	50%	100%

Additional credits for HGS, EFVS, SVS are in development

Airline Operators of HGS

Africa

Americas

Asia/Pacific

Europe

Middle East

United States B737 HGS Equipage

American Airlines

78%

U.S. based B737 equipped with HGS

DELTA

Alaska AIRLINES

Southwest

In Conclusion

- Operating environment and infrastructure in Southeast Asia warrant broader use of Head-Up Displays
- HGS allows airlines to run more economically by:
  - Reducing the number of flight disruptions
  - Maximizing safety margins
  - Saving unnecessary maintenance costs
- Vision technologies offer a significant operational opportunity for airlines

HGS & Vision Systems are a necessary consideration