How GNSS Enables Precision Farming

John Deere Intelligent Solutions Group | December 2014

Feeding a Growing Population

Enables those who feed the world.

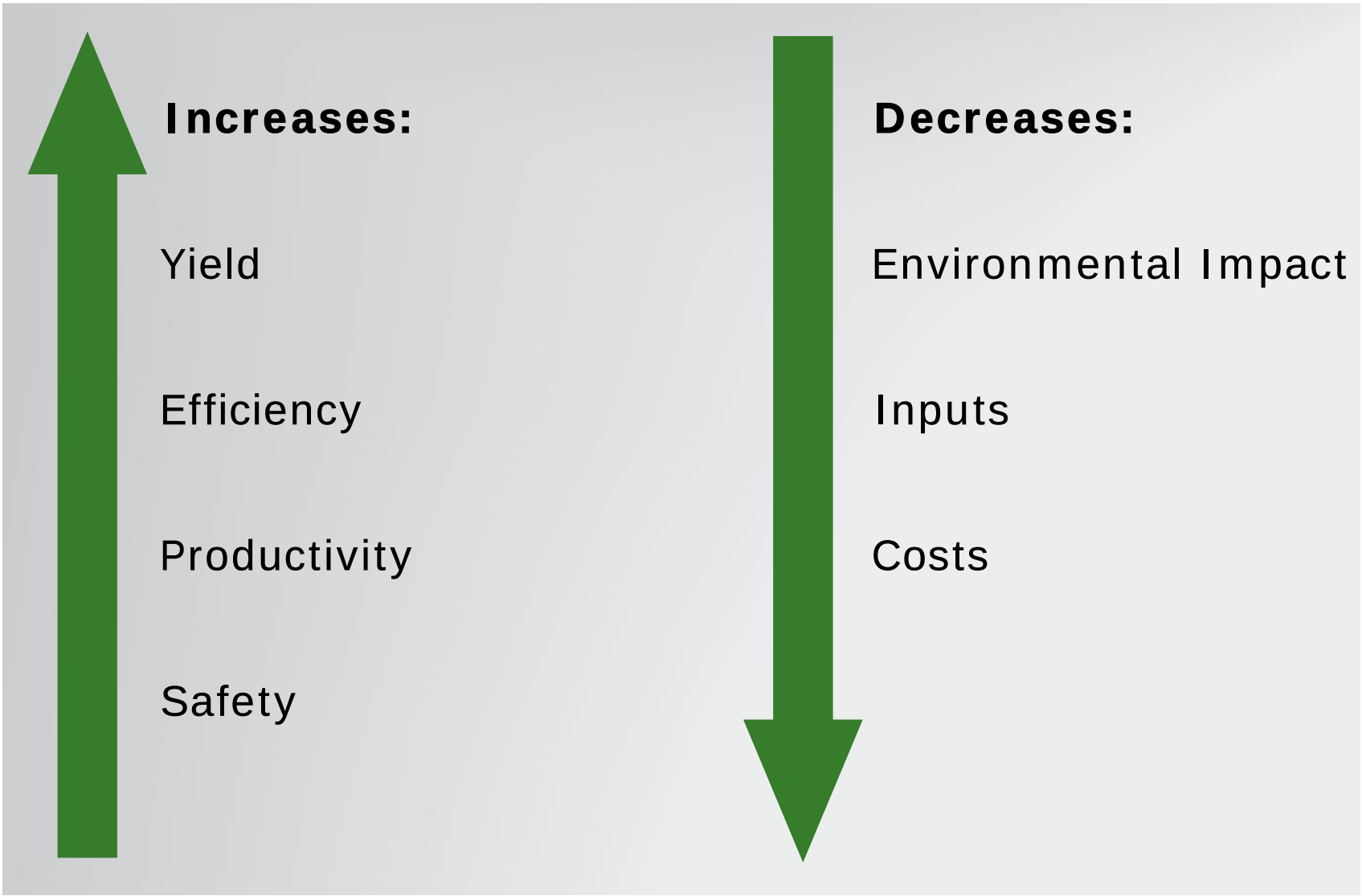
Immediate and Ongoing Needs

+ population growth (more to feed)
+ urbanization (decrease in arable land)

Double food production by 2050 to meet world demand.

To meet this need – every inch matters.

GPS Enabled Precision



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Precision Seeding

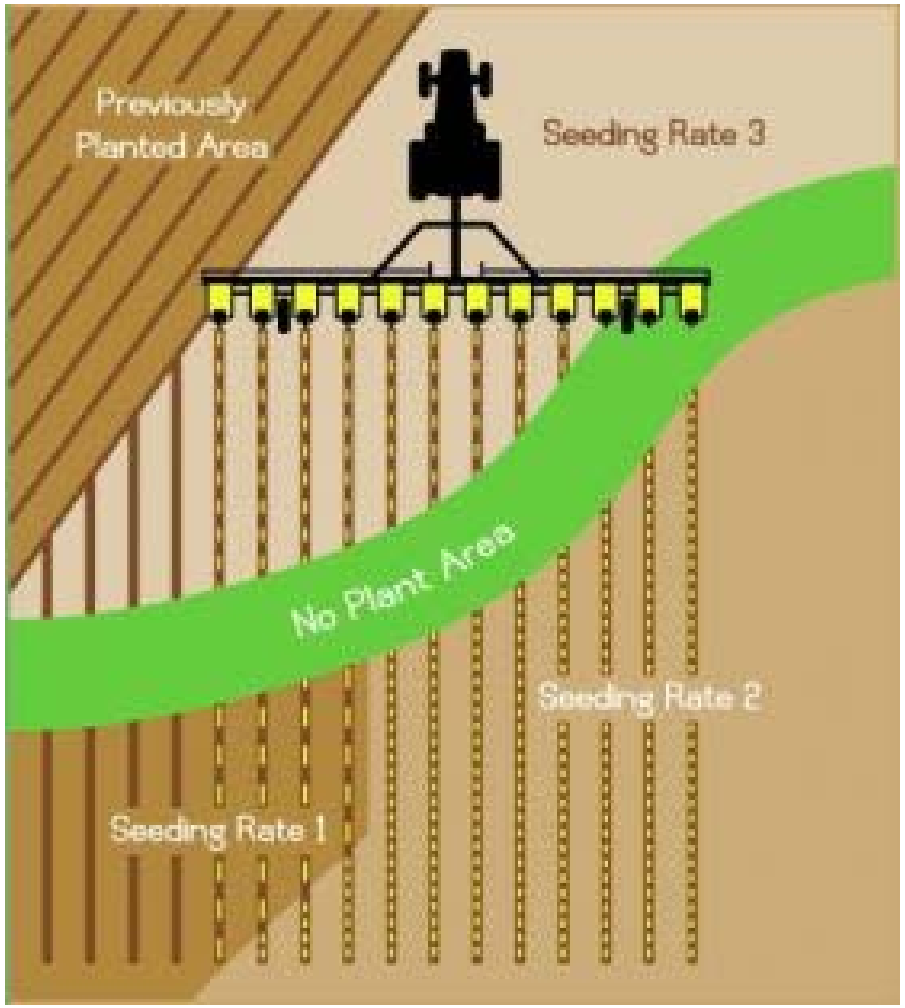

Image Source: http://farmindustrynews.com/site-files/farmindustrynews.com/files/imagecache/galleryformatter_slide_penton/gallery_images/web07RAVNplantcontrolillus.jpg

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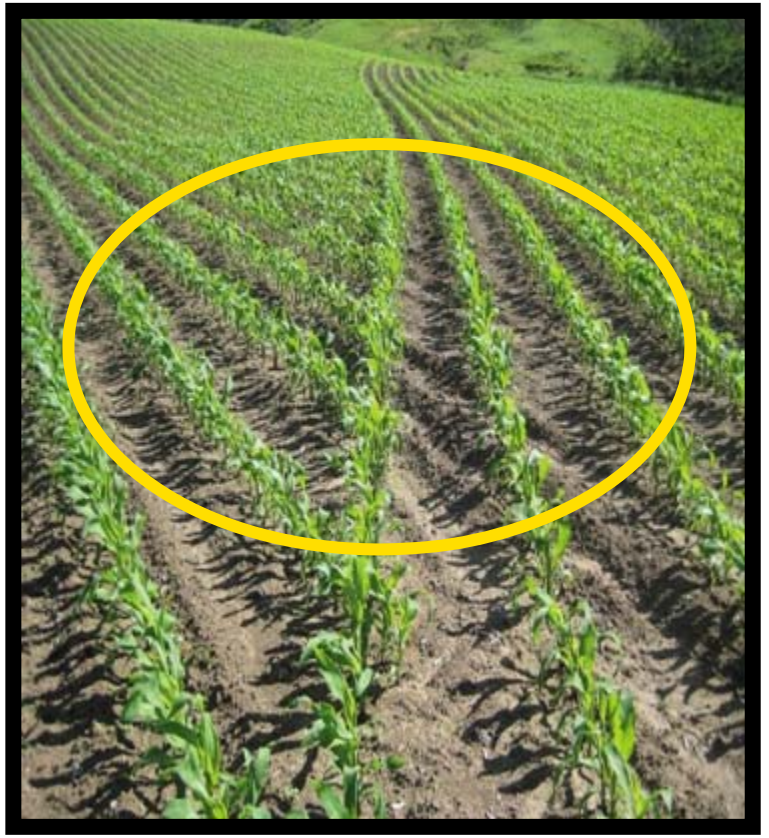
GPS Enabled Precision Ag

Field Planted without Swath Control

Field Planted with Swath Control Pro™



GPS Enabled Precision

GPS Enabled Precision Ag

Overlap used to be measured in feet.

With precision GPS, overlap is now measured in inches.

GPS Enables Operator Efficiency

Decreases Fatigue

Increases Health & Safety

Enables Night-time Operation

Water Optimization & Precise Planting

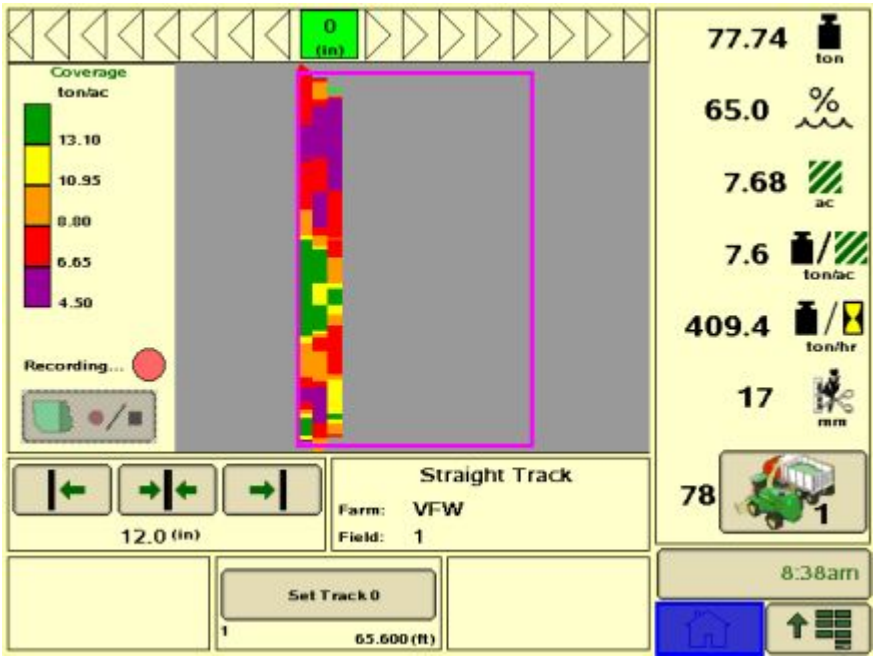
Irrigation structures easily damaged by machinery

- Especially subsurface tubes and tapes

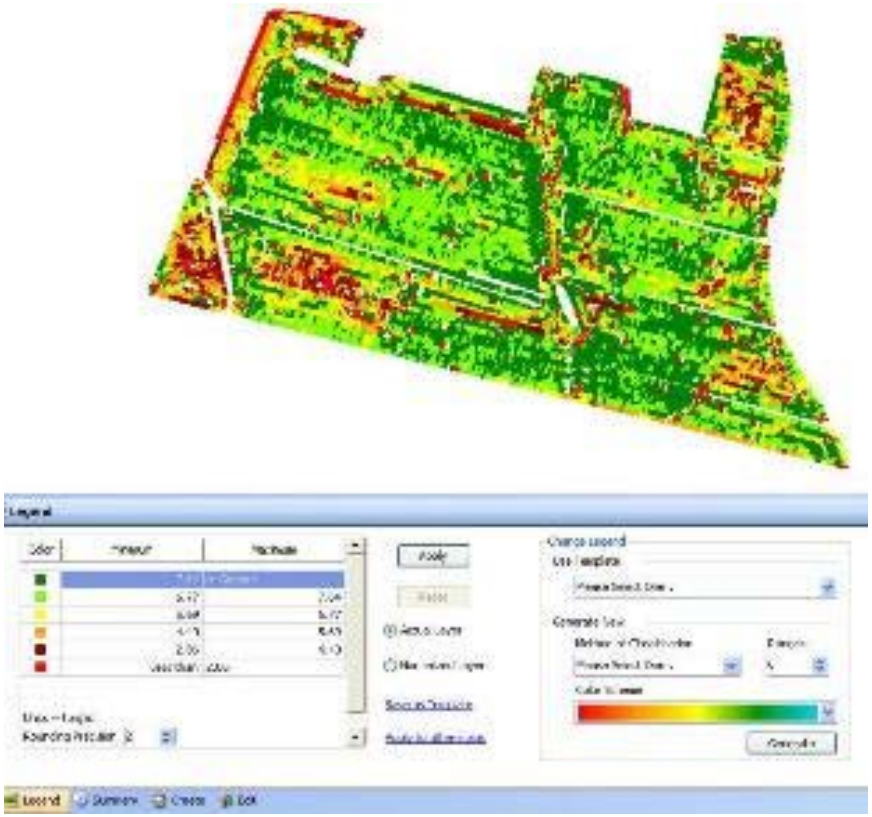
Mapping of irrigation infrastructure allows planting near drip lines

- More water for crop
- Less water for weeds

Precision Enabled Decision Making



Record and Adjust While Operating



Actionable Information for Analysis and Decision Making.

Improved Agricultural Productivity

Yield Mapping – used by 80% of grain combine customers in US

- Provides insight for precise seed placement, pesticides and fertilizers

Auto Guidance – used by 65% of the large agriculture producers in US

- Reduced errors in overlap of tillage, seeding and spraying
- Reduced operator fatigue
- Opportunity to use local unskilled operators

Improved Output

- Reduced overlap = fewer passes through the field
- Less compaction implies higher yield
- Less tillage required – less fuel, less carbon release and lower food cost

Future Gains

- Additional advancements needed to feed a growing population

Specific Input Cost Savings

- **Annual Cost impact: $8.2 billion**
  - Reduced chemical and fertilizer: $4.8 B
  - Reduced seed costs: $1.5 B
  - Reduced fuel consumption $0.5B
  - Labor savings $1.4 B
- **Other Cost impacts**
  - Operation in darkness, fog and high winds
    - 100% GNSS availability essential
  - Optimal planting time can result in difference of 1% yield per day

Improved Environmental Impact

Reduced pesticide and fertilizer usage

- GPS has saved between 7% to 10% (17.5 to 25 million acres) annually from receiving unneeded pesticide and fertilizer applications.

USDA data shows technology impact on corn production—compared to 1987 *(Impossible without GPS)*

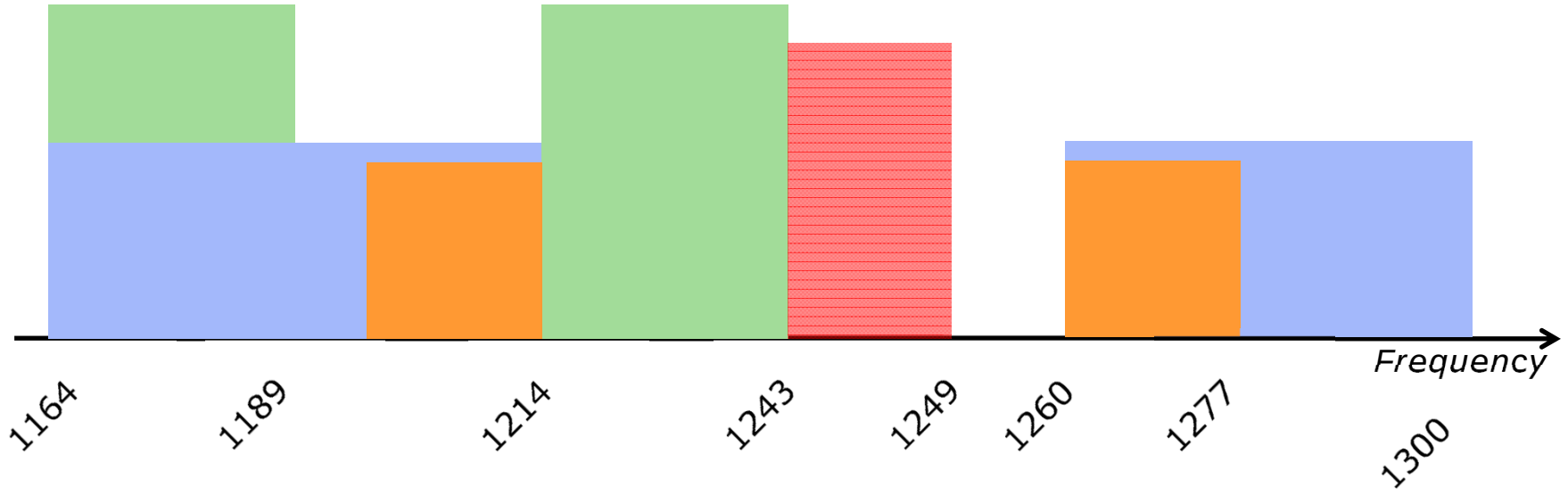
- Land required to produce a bushel of corn reduced by 37%
- Precision tillage has reduced soil loss by 69%
- Energy required for production reduced by 37%
- Carbon emissions reduced by 30% per bushel

Downlink Frequencies Used in Agriculture -Low Bands

GPS L5
Galileo E5a and E5b
Beidou B2

GPS L2
Glonass G2

Galileo E6
Beidou B3



Frequencies in MHz

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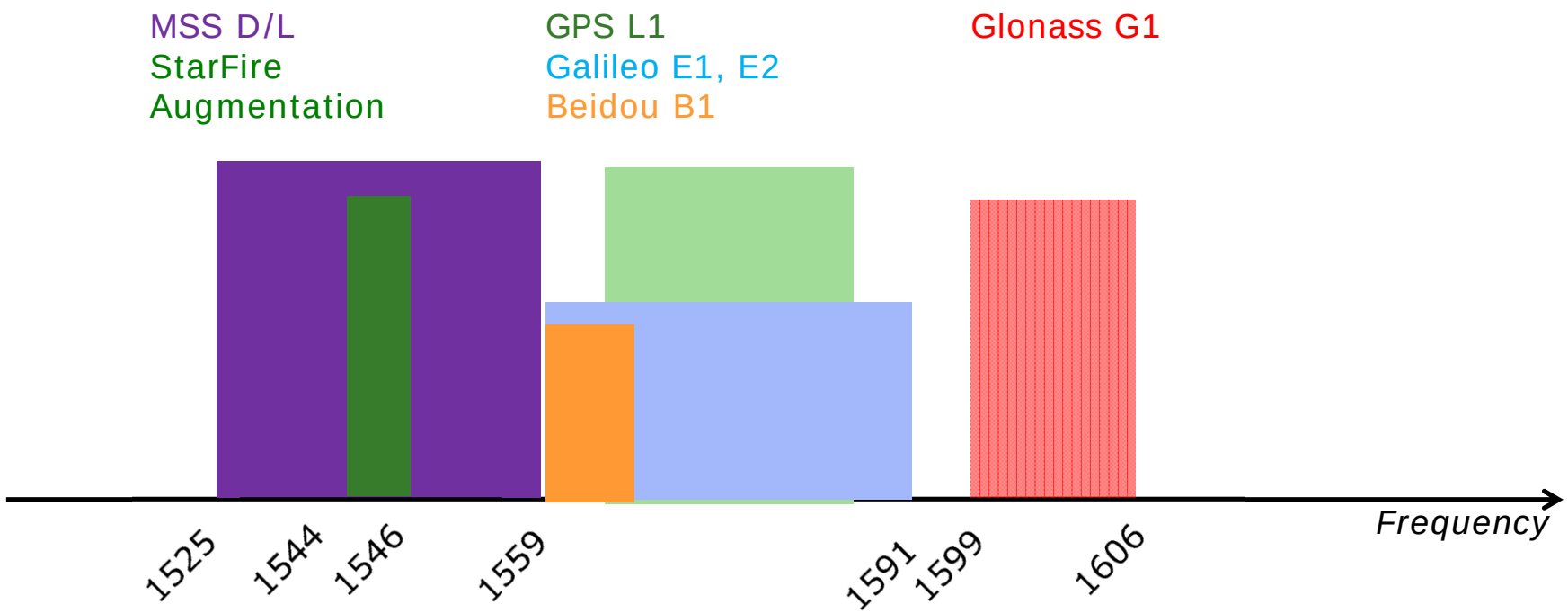
Downlink Frequencies Used in Agriculture -High Bands



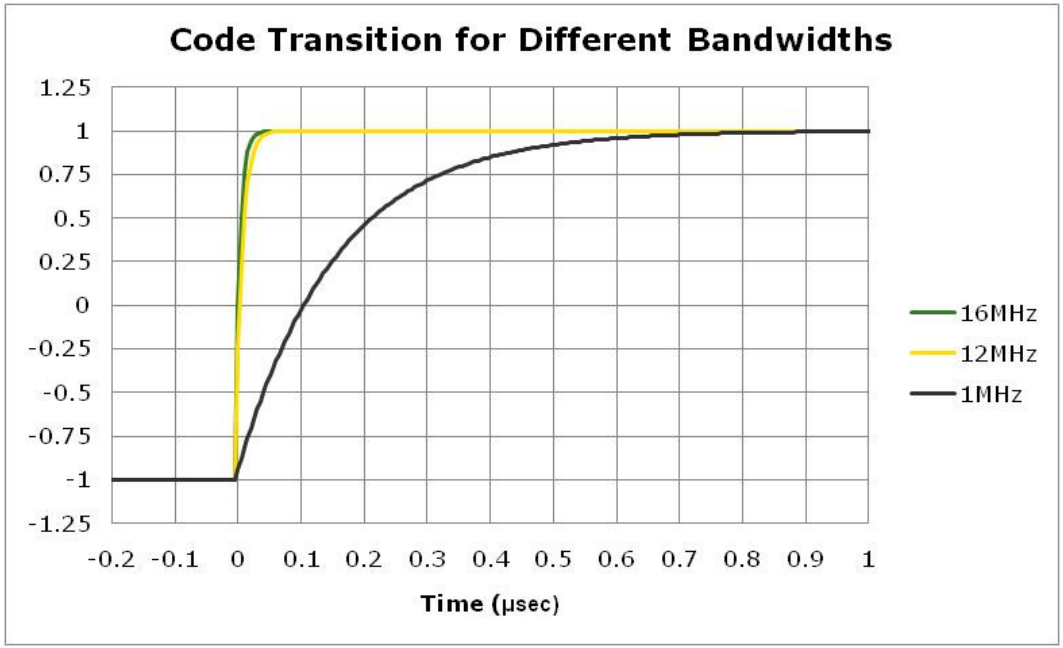
Frequencies in MHz

GNSS Accuracy is a Function of GNSS Bandwidth

GNSS is based on range measurements to the satellites (pseudoranges)

- Measure time of arrival (TOA) of spreading code transitions
- Accuracy of TOA measurement depends on sharp code edges

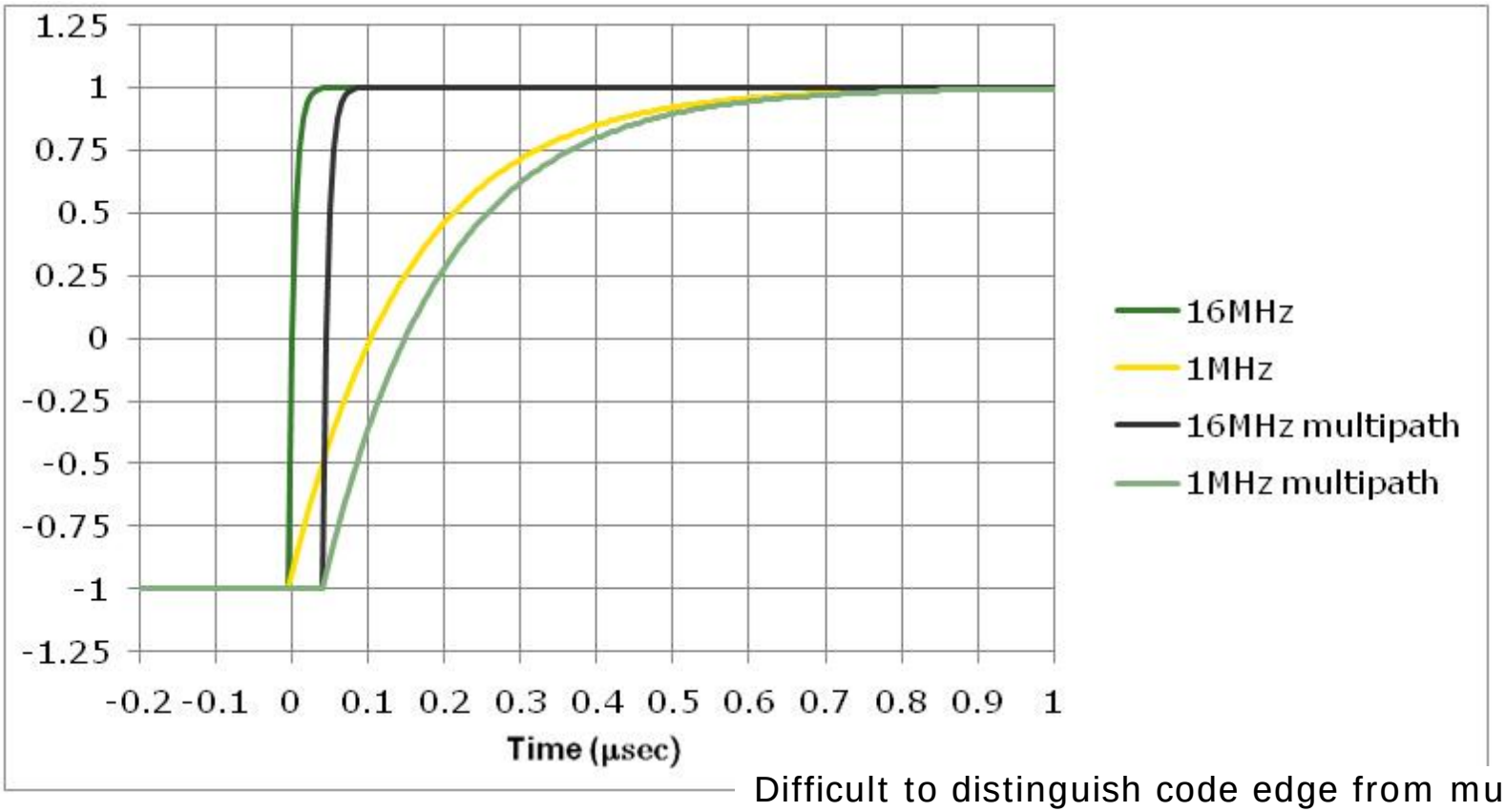
- Sharpness of code edges depends on bandwidth
  - Most of energy is in 2 MHz for L1 C/A code, but much of the information on sharpness is in the lobes
- Navigation accuracy depends on wide bandwidth



Multipath Mitigation

Difficult to find code edge in multipath-distorted signal

Need sharp code edges to see direct signal before multipath signal



Difficult to distinguish code edge from multipath

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