**Low Power Wireless Technologies**

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**APEC 2012 Industry Session**

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## Low Power Wireless Session Overview

- Review industry standards and wireless evolution with a focus on IEEE 802.15.4 radios
- Wireless compatibility with energy harvesting power supplies
- Wireless power profiles and design techniques
- Energy harvesting-based wireless demo to highlight key concepts



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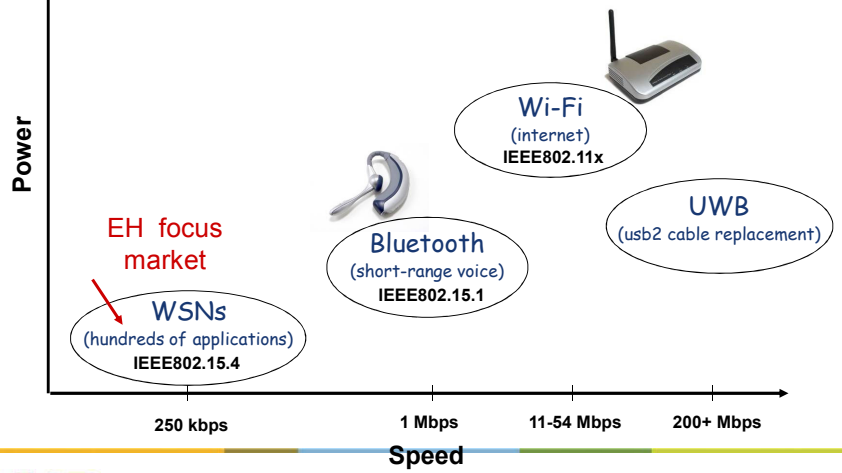
# The Wireless Evolution

- Standards-based wireless systems become pervasive:-
- New standards catalyze market growth








# RF Comparison Usage and Scenarios

*Increasing priority*

| | Implementation Price | Power | Co-existance with other networks | Large-scale Networking stack | Small-scale Networking stack | Wireless Microcontroller design route | Interoperability | Encryption | Datarate |
|---|---|---|---|---|---|---|---|---|---|
| **Bluetooth** | Low | High | Poor | No | Yes | No | Yes | Med | High |
| **Wibree** | Low | Low | Poor | No | Yes | No | Yes | Med | High |
| **Proprietary** | Low | Low | No | No | No | Yes | No | No | Low |
| **802.15.4** | **Low** | **Low** | **Good** | **Yes** | **Yes** | **Yes** | **Yes** | **Good** | **Low** |
| **WiFi** | High | High | Good | Yes | Yes | No | Yes | Good | High |

- **IEEE802.15.4 offers optimal solution**
  - Designed to operate in large networks of devices
  - Lowest cost. Flexible design solution for many different applications
    - » No 'application-profiles' ensures design flexibility
  - Lowest power with prospect of interoperability
  - Co-existence with other wireless networks (e.g. Wi-Fi)

What about range?





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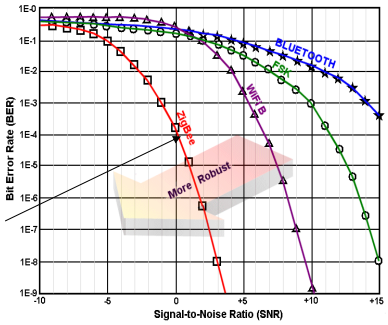
# IEEE 802.15.4 Radio Characteristics

ZigBee is based upon IEEE 802.15.4 which has a much lower BER for a given SNR

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  - Designed to operate in large networks of devices
  - Lowest cost. Flexible design solution for many different applications
  - Lowest power with prospect of interoperability
  - Co-existence with other wireless networks (e.g. Wi-Fi)
  - Offset Phase Shift Keying is superior to Bluetooth and WiFi modulation in high noise environments





# ISM Band

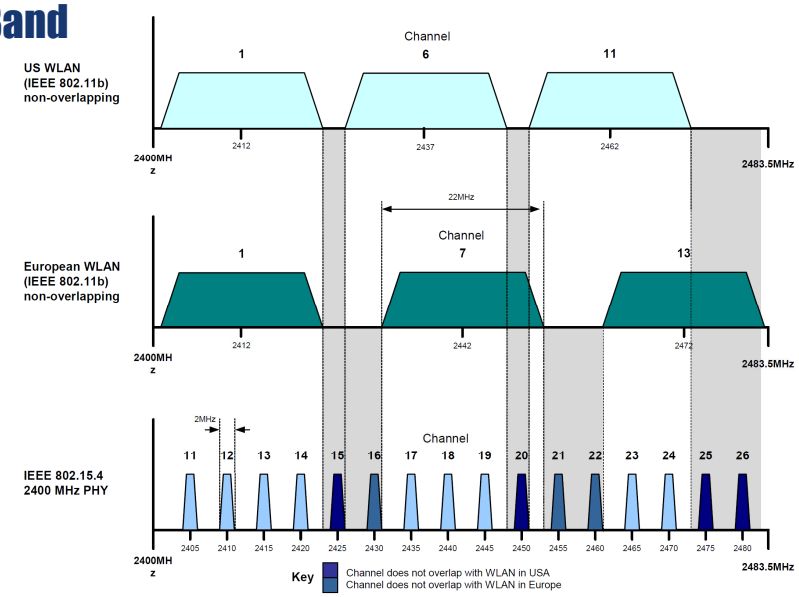






Photo courtesy of JN-AN-1059 & JN-AN-1079

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## Bluetooth versus 802.15.4

### When to use Bluetooth

- When connecting to a device that already has Bluetooth
  - » PDA or cell phone connections
  - » Why add another radio, use what already exists
  - » Use the standard profiles if they work well
- Stereo audio
  - » High data rate
  - » Excellent CD quality audio
- Co-existence is not an issue
  - » Interference with WiFi channels that cause missed packets
  - » Interference with large number of Bluetooth users in one area
  - » If these are not a concern, then Bluetooth is a good solution




## Bluetooth versus 802.15.4

### Problems with Bluetooth that 802.15.4 solves

- Bluetooth devices change every 18 months
  - » It is a consumer electronics driven specification which requires new product introductions and improvements
  - » New specification issued and so new devices replace old ones
  - » 802.15.4 is an industrial standard which has not changed the hardware specification for 10 years.
- Low immunity to noise interference.
  - Bluetooth hops channel s and was intended for consumer grade communication.
  - 802.15.4 devices stay locked into a channel and switch only if noise level gets too high.
- Networking of devices
  - 802.15.4 can be networked through a variety of configurations.
  - Bluetooth is really intended only for point to point communication.

# Bluetooth versus 802.15.4

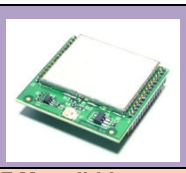
**Problems with Bluetooth that 802.15.4 solves (continued)**

- Fast connect times
  - Bluetooth pairing with a new device takes several seconds
  - 802.15.4 is 6mS or less connect time
  - Faster connect times means lower power consumption
- Co-existence
  - » Stay locked in one channel
  - » Blacklist channels where WiFi is being used
  - » Prevents interfering with WiFi data
  - » Have 10+ 802.15.4 devices per channel without an issue





# IEEE802.11 vs IEEE802.15.4 Module Solutions

| | |  |  |  |
|---|---|---|---|---|
| | **Part Number** | **RF Monolithics WSN802G** | **NXP JN5148-001-M00** | **NXP JN5148-001-M04** |
| | **Technology** | IEEE 802.11 b/g | IEEE 802.15.4 | IEEE 802.15.4 |
| | **Frequency** | 2.4GHz | 2.4GHz | 2.4GHz |
| | **World Wide Acceptance for All Channels** | No. Country specific | Yes | Yes |
| ➡ | **Active Power** | 200mA | 17mA | 110mA / 23mA |
| ➡ | **Sleep Current** | 8uA | 2.8uA | 2.8uA |
| △ | **Data Rate** | 11Mbps / 54Mbps | 250 Kbps | 250 Kbps |
| | **Distance** | 250m / 820ft line of sight | 400m / 1,300ft line of sight | 6Km / 19.685ft line of sight |
| | **Dimensions** | 25.4mm x 26.7mm | 18mm x 32mm | 18mm x 41mm |
| ➡ | **Pricing at 1pc / 10K pcs** | Roughly 3X of standard power 802.15.4 module | $X | 20 percent more than std power |

△ Data rate is one advantage for WiFi



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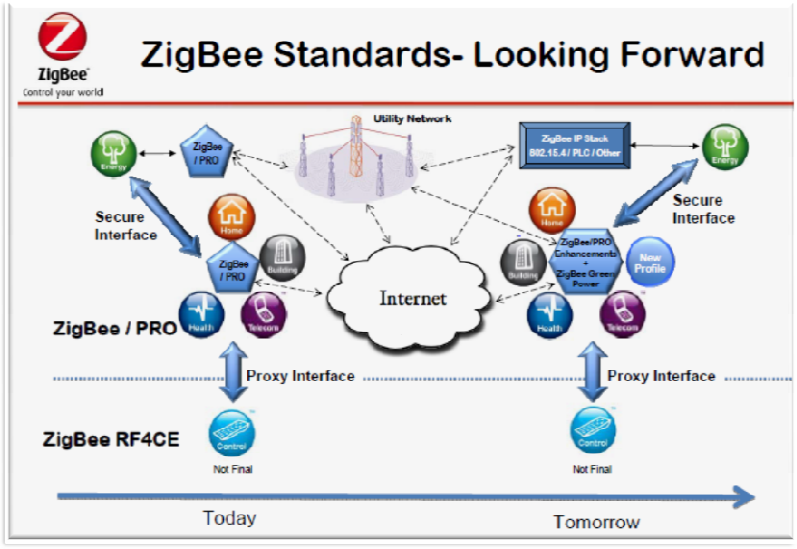
# Wireless Networking Standards Comparison

| | JenNet-IP | ZigBee SL | ZigBee HA | Wi-Fi | ZigBee-IP |
|---|---|---|---|---|---|
| **Routing Topology** | "Mesh Under" Tree with self healing | Mesh | Mesh | Star | "Mesh Over" Mesh |
| **Max. Nodes** | 500 | TBD | 500 | 254 | 50 |
| **Availability** | Now | Q1/2012 | Now | Now | 2012 |
| **IP Based** | Yes (6LoWPAN) | No | No | Yes | Yes |
| **Stack Size (excl. application)** | <85KB | ~128KB | ~96kB | >256KB | <200kB |
| **Cost** | $ | $$ | $$ | $$$ | $$$ |
| **Frequency** | 2.4GHz | 2.4GHz | 2.4GHz | 2.4-5GHz | 2.4GHz |
| **Standby power** | Medium <150mW | medium <150mW | medium <150mW | high | Medium <150mW |
| **Operating Power** | Low | Low | Low | High | Low |
| **Optimized commissioning** | Yes | Yes | Yes, but no simple commissioning | No | Designed for Smart Energy apps |
| **Licensing Cost** | Free | ZB Alliance membership & product cert. fees, potential 3rd party IP costs | ZB Alliance membership & product cert. fees, potential 3rd party IP costs | Wi-Fi Alliance membership & product cert. fees. | ZB Alliance membership & product cert. fees, potential 3rd party IP costs |
| **Interoperability** | IPv4 and IPv6 | ZSL only | ZHA Only | any IP Device | ZB SE 2.0 and IPv6 |
| **Development Complexity** | Low | High | High | High | High |





# ZigBee Roadmaps




Courtesy ZigBee Alliance





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## Sending Data from Energy Harvesting Node

- Energy harvester generates an energy pulse
  - From the physical action of pressing the switch, light, etc
  - ZigBee Green Power requires 200uJ of energy
  - No stored energy available between switch presses
- Receiver
  - Requires battery or AC voltage
  - Receiver always on to receive packet
- Sending a packet
  - Not enough time to send a fully acknowledged packet
  - Not enough energy to join the network
- Transmitting with minimal amount of energy
  - Send stream of data with three packets
  - Redundancy assures that one of the three packets gets through
  - Acceptable for most applications, such as lighting
- Where should it ***not*** be used
  - Life critical applications, such as emergency door exit
  - Any application which requires acknowledgement of data





## Packet Format

- Low power operation
  - Wake, load program code, calibrate radio
  - Transmit 3 packets at full output power (2.5dBm) using just 15.5mA
  - Sleep with RAM held between transmissions
- Boot code size just 1kbyte
  - Fast bootup
  - Conserves battery life
- 19byte total transmitted packet (13 bytes MAC frame plus 6 byte header)
  - Standard IEEE802.15.4 frame
  - Sequence number stored in external EEPROM when packet is sent
    - » Ensures each packet has unique sequence number
- Must be fixed channel





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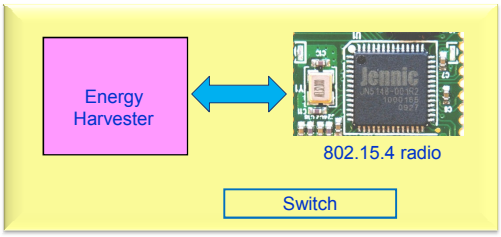
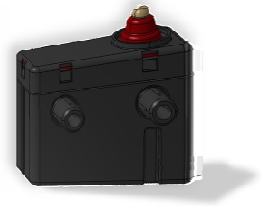
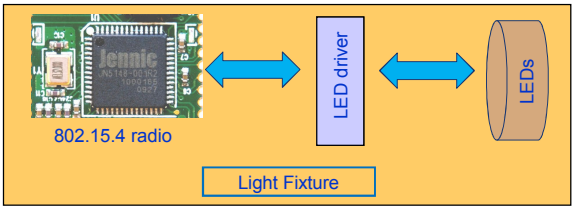
## Demo Block Diagrams




Switch harvester and pcb




Light with custom pcb

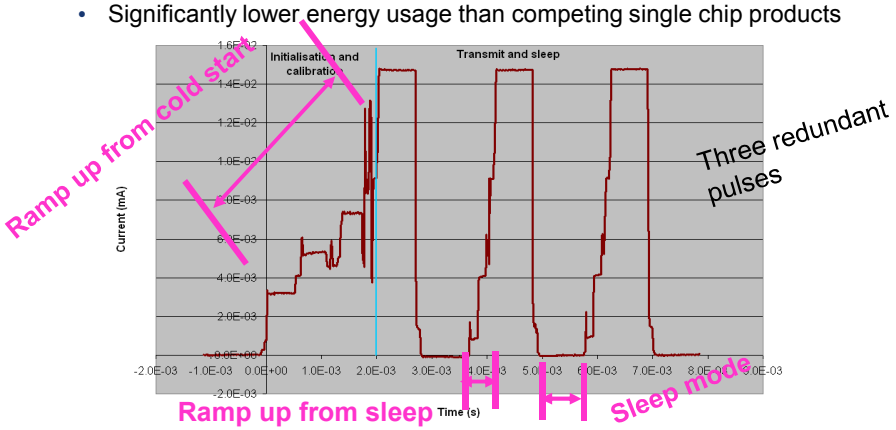







## 802.15.4 Current Profile (Minimum Required)

- Very low overall energy consumption due to very low TX current
- Significantly lower energy usage than competing single chip products




Full solution is achieved using just 50uC of charge (100uJ at 2v)





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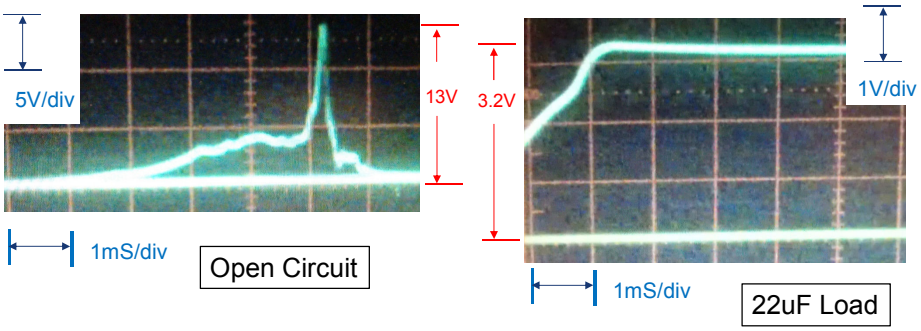
## Current Profile (Supplied by Energy Harvester)

- More than enough current is supplied
- Might be capable of transmit and receive operations

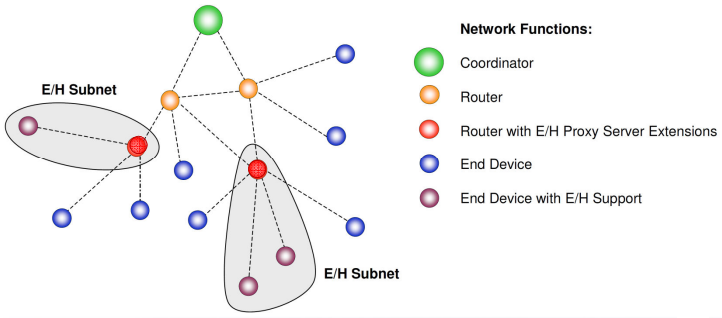



Single depression or release of switch




## Wireless Network Software

- Configured to support intermittent end device transmission
  - Ready to service requests when the end device needs
- Uses a Proxy Server
  - Powered Routers – always ready to receive from E/H end devices




Interoperate with ZigBee or IP (6LoWPAN) Nodes

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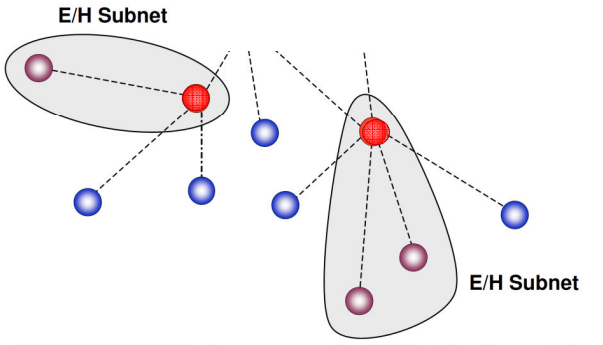
## Wireless Proxy Server

- Differentiates from other Energy Harvesting technologies
- Receives E/H data and sends it along the network
- Remote device can be operated by E/H activity

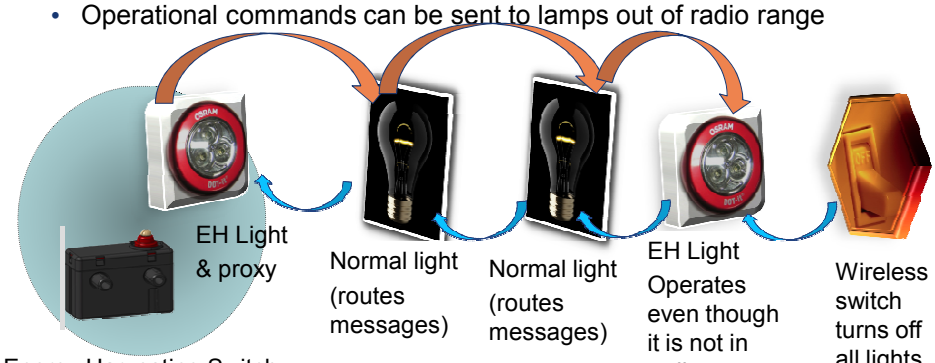



Interoperate with ZigBee or JenNet IP (6LoWPAN) Nodes




## Networking stack important for Energy Harvesting

- Light can operate from energy harvesting switch or from network command
- At the end of the day, light switch can turn all lights off without having to activate all the energy harvesting switches individually
- Operational commands can be sent to lamps out of radio range







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## Commissioning the Network

**How to setup the network is important**

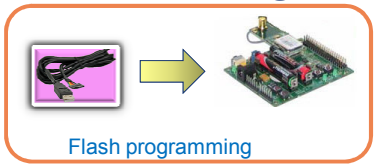
- Assign the right switch to the right lamps
- Assign channels
- Pick a PAN id

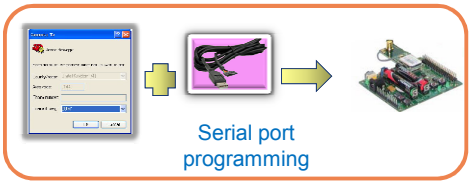
**Needs to be easy to do**

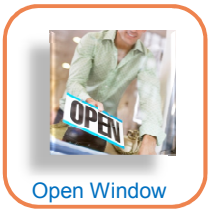
- Limit the software required
- Better if flash programming is not required



## Commissioning Methods

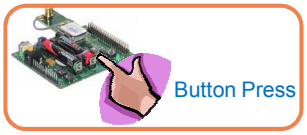


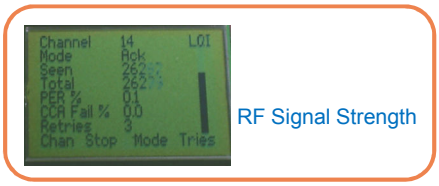









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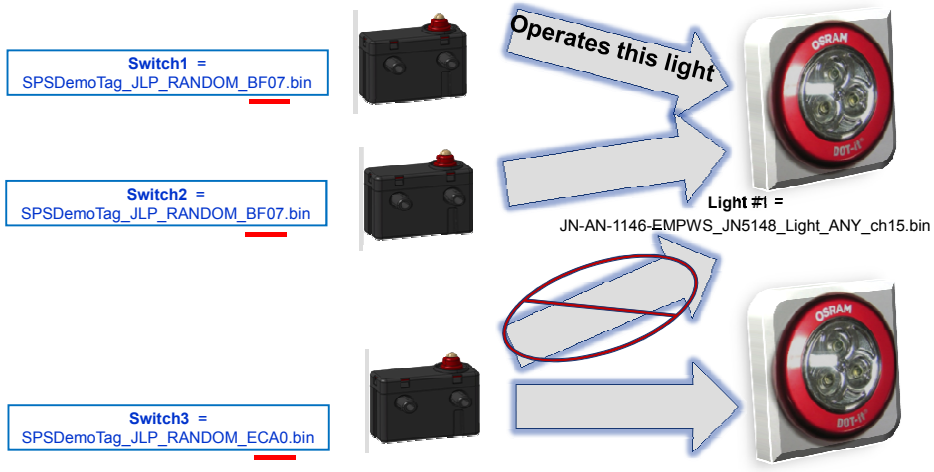
## One Method of Commissioning








## Summary

- Energy harvesting technology is an important technology for powering wireless communications
- Wireless technology choices are determined by the amount of energy harvested and the tasks to be accomplished
- There are several ultra-low power wireless choices
- Optimizing the wireless network initialization, device registration process, and communication message duration is essential for proper network operation of Energy Harvesting powered wireless devices.





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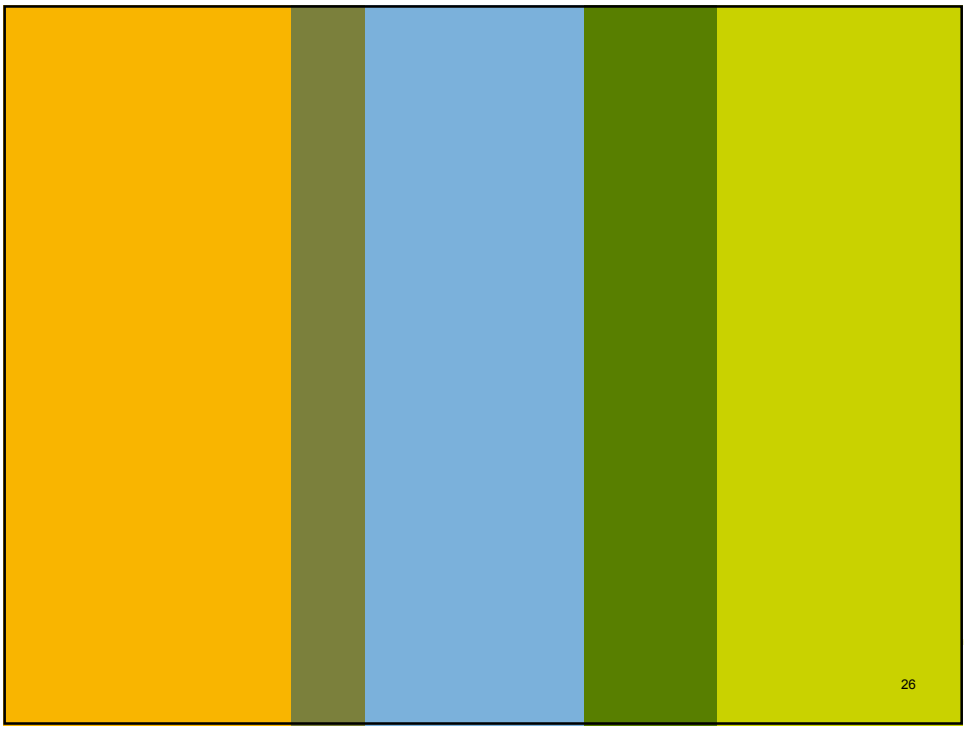
## Conclusion

- Any Questions?





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