SPMD Usecase
Entertainment Lighting Controls

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with input from Eric Johnson, Cisco
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Intro

- Entertainment Lighting is *dynamic* and changes in real-time

- Requires far more bandwidth than architectural lighting
  - But still isn't that much in network terms

- Installation practices assume a daisy-chain topology
  - RS-485 still used extensively
  - Ethernet relegated to a backhaul technology

- Mix of permanent and portable cables
  - Similar to microphone cable
  - 5-pin XLR connector with two twisted pairs in *most* cables

# ANSI DMX512 Control Protocol

- Based on RS-485 @ 250 kbps

- Best-practice distance limits are 1,000ft with 300ft max between nodes
  - User installed terminator

- Portable cabling resembles microphone cabling, but has 2-pairs and 5 pins (XLR)

- Permanent cabling is often Cat 5e

- Aside: Portable Ethernet cabling often uses an XLR-style shell
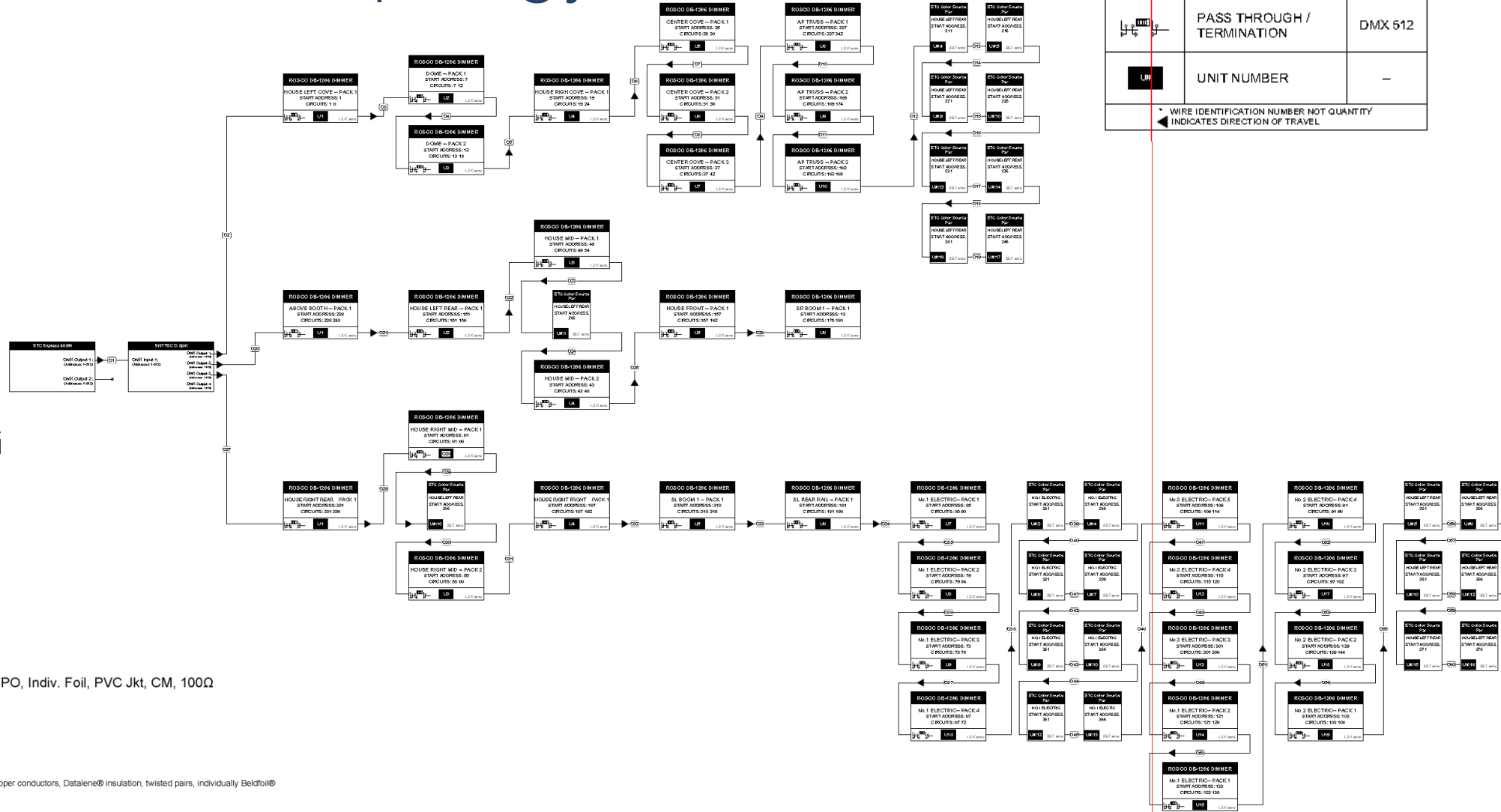
Typical Physical Topology

- Average Theatre Space
  - Stage Width ~ 10m
  - Stage to Control Room < 100m

- Control Topology
  - RS-485 Only
  - May use active splitter
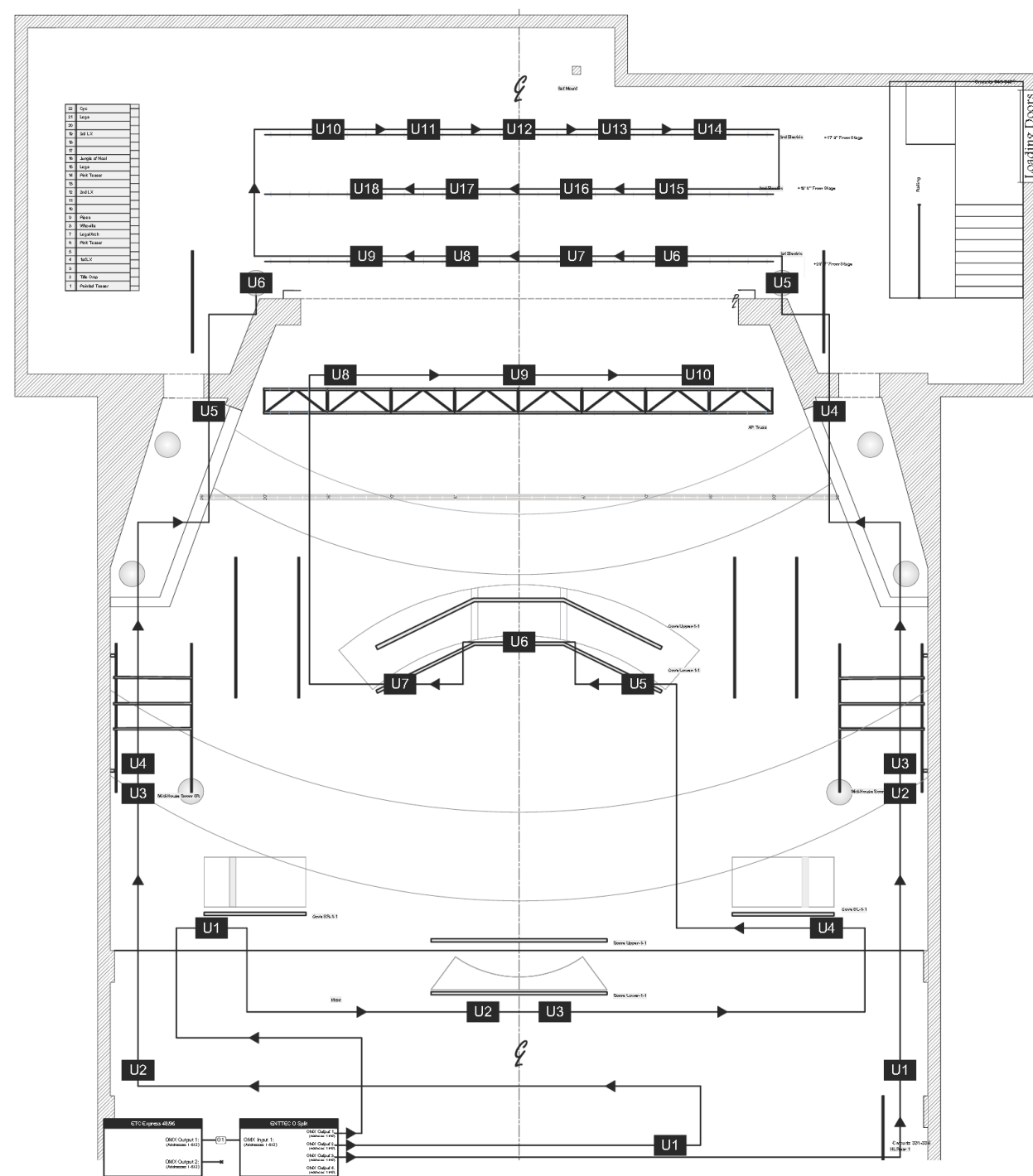
Typical Network Topology

- Exclusively daisy chain

- ~30 nodes per chain

- Cable plant is Belden 9729 2-pair 24 AWG

BELDEN
SENDING ALL THE RIGHT SIGNALS

Product: 9729

RS-232/422 Low Cap, #24-2pr, FPO, Indiv. Foil, PVC Jkt, CM, 100Ω

Product Description
Computer EIA RS-232/422, Digital Audio Cable, 24 AWG stranded (7x32) tinned copper conductors, Datalene® insulation, twisted pairs, individually Beldfoil® shielded (100% coverage), 24 AWG stranded tinned copper drain wire, PVC jacket.

SYMBOL	DESCRIPTION	SIGNAL
D*	BELDEN #9729	DMX 512
	PASS THROUGH / TERMINATION	DMX 512
U##	UNIT NUMBER	—

NETWORK DIAGRAM KEY

* WIRE IDENTIFICATION NUMBER NOT QUANTITY
◄ INDICATES DIRECTION OF TRAVEL
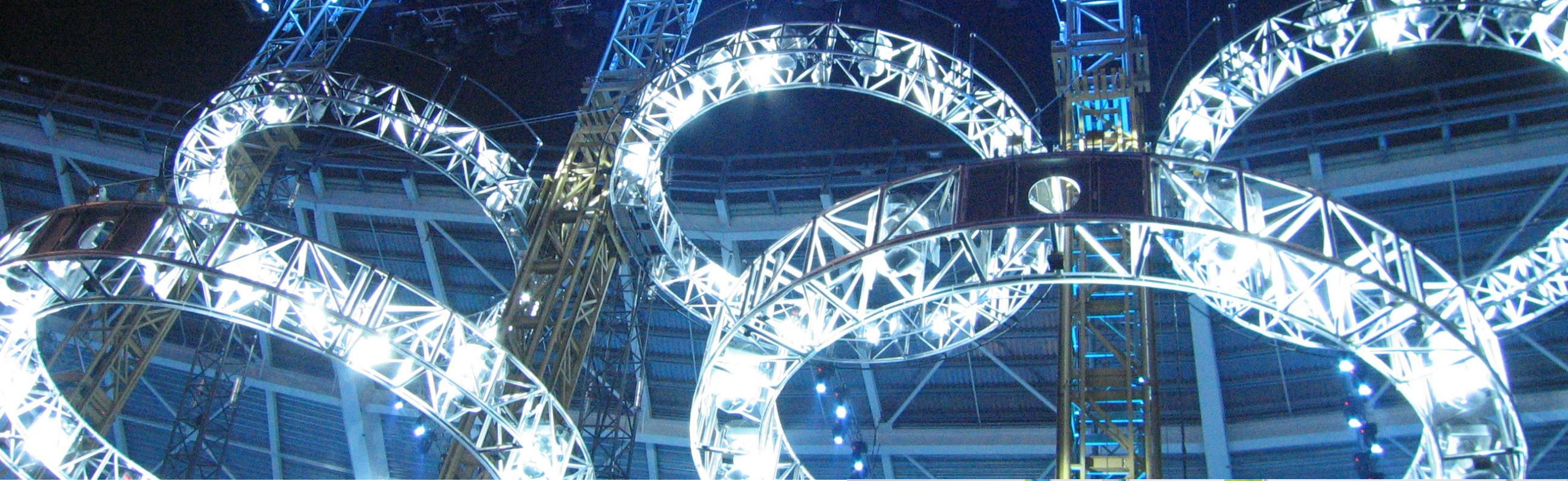
Installation Tour:
2006 Sports Stadium in Torino, Italy
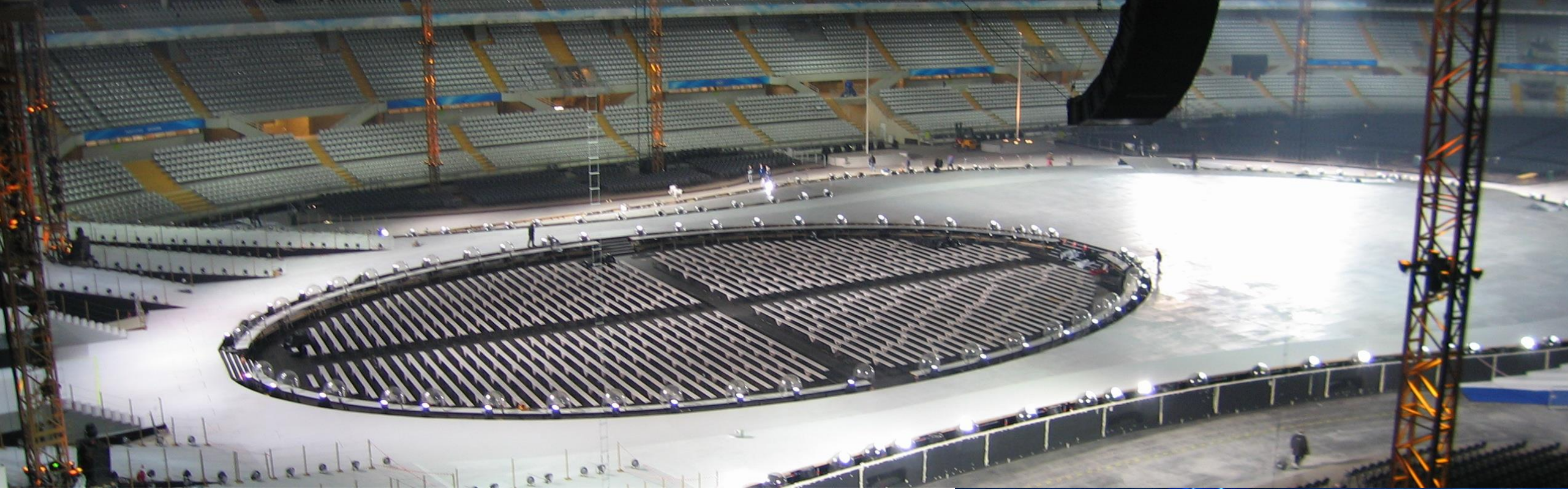
Purpose-Built Oval Stadium
~600m circumference

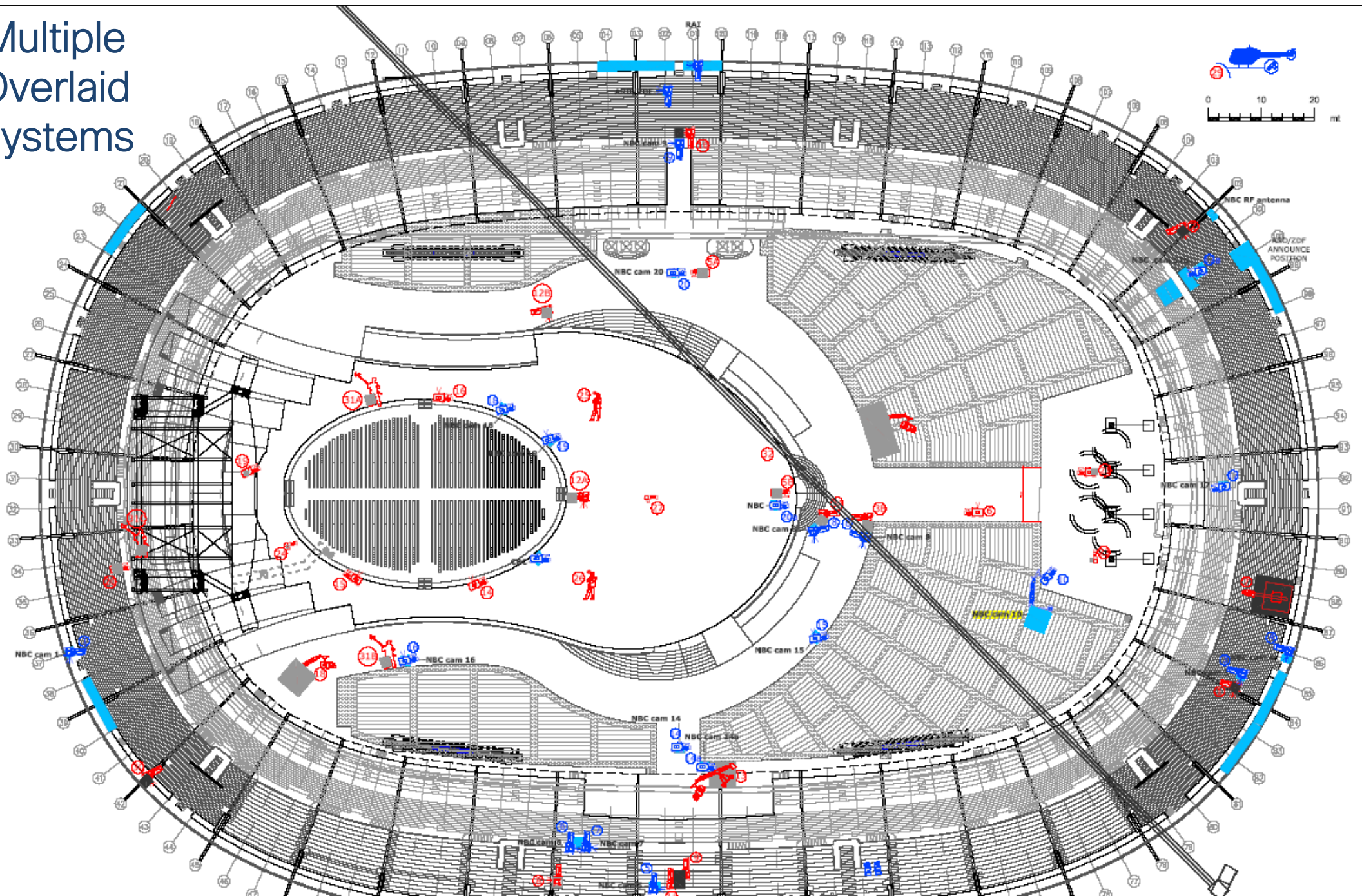# Multiple tower clusters
plus perimeter arrays
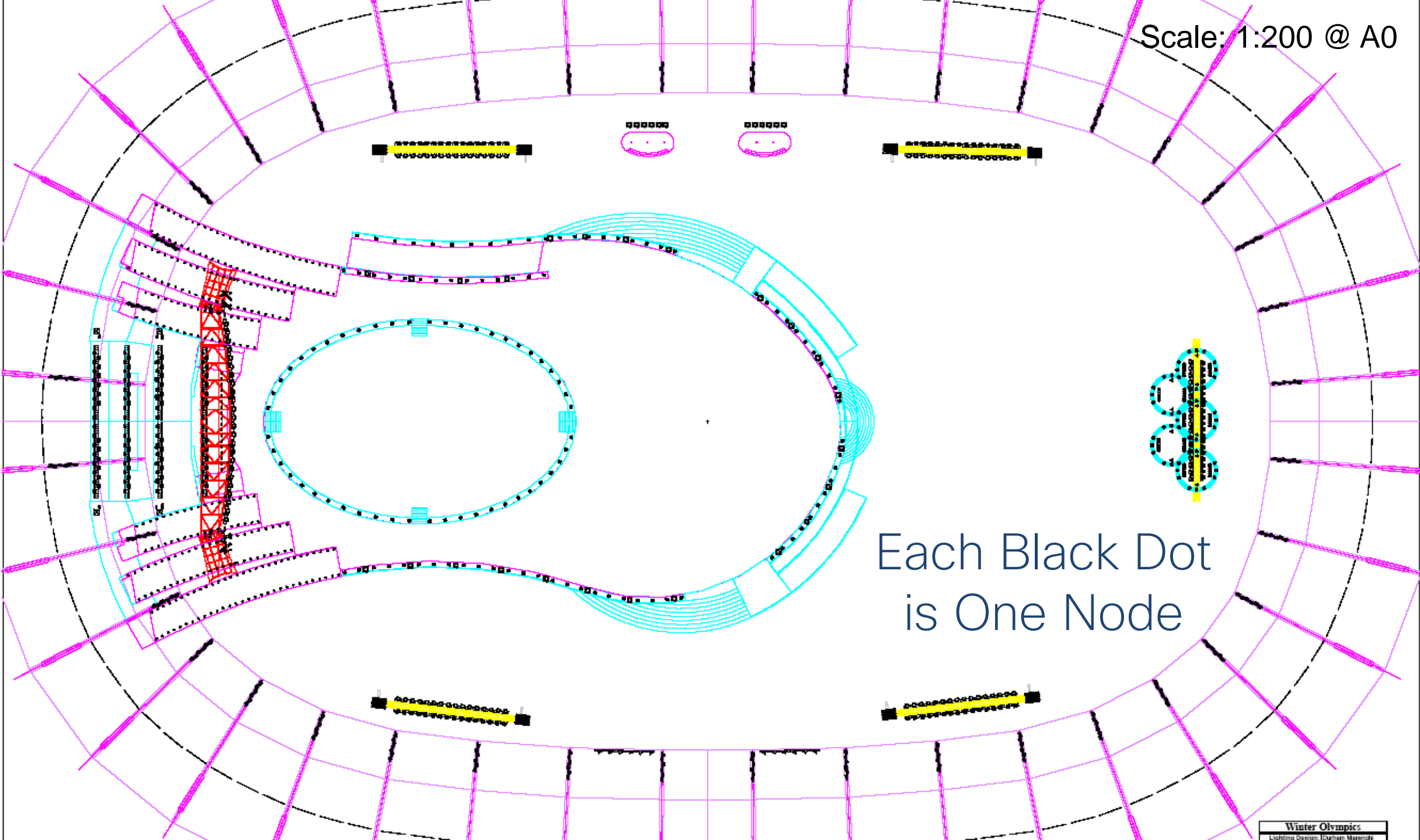
~60 Nodes per tower

Multiple Overlaid Systems

A	1.8 x 1.8 x 0.5
A1	1.8 x 1.8 x 0.5
A2	21.6 x 1.8 x 1.40
B	1.8 x 1.8 x 0.5
B2	3.6 x 1.8 x 0.97
B3	3.6 x 1.8 x 1.50
B4	3.6 x 1.8 x 0.94
B5	3.6 x 1.8 x 1.50
B6	10.8 x 1.8 x 1.40
B7	1.8 x 1.2
C	1.8 x 1.8
C1	1.8 x 1.8
D	5.0 x 10.0
E	1.8 x 1.8
F	1.8 x 1.8
G	Roving
H	5.0 x 5.0
I	1.8 x 1.8
I1	1.8 x 1.8 x 0.5
I2	1.8 x 1.8 catwalk
J	2.0 x 1.5 x 1.0
K	1.8 x 1.8 gondola
K1	1.8 x 1.8 x 0.5
K2	21.6 x 1.8 x 1.40
K4	1.8 x 1.8
L	2.0 x 1.5 x 1.0
M	1.8 x 1.8
MA	1.8 x 1.8
N	5.0 x 5.0
O	Roving
P	Roving
Q	Roving
R	5.0 x 5.0
S	1.0 x 1.0
T	1.0 x 1.0
U	1.0 x 1.0
V	1.8 x 1.8
V1	3.6 x 1.8 catwalk
W	0.5 x 0.5
X	0.5 x 0.5
Y	Roving
Z	Roving
AA	Roving
BB	1.8 x 1.8
CC1	1.8 x 1.8
CC2	1.8 x 1.8
CC3	1.8 x 1.8
DD	3.0-5.0 x 5.0 x tbd
GG	10.8 x 1.8 x 1.40
II	10.8 x 1.8 x 1.40
LL	1.8 x 1.8
LL1	1.8 x 1.8 x 3.10
MM	1.8 x 1.8
NN	4.0 x 4.0 x 1.0
OO	1.8 x 1.8
PP	1.8 x 1.8
QQ	1.8 x 1.8 in US athlete area
RR	1.8 x 1.8 in US athlete area
SS1	4.0 x 1.5 gondola
TT	2.0 x 1.5 x 1.0
UU	1.8 x 1.8 x 0.5
XX	1.8 x 1.8 in CAN athlete area
YY	63sqm
ZZ	5.0 x 3.0

APo NBC 7.5 x 3.5 x tbd
APo ARD ZDF 4 x 4 x tbd

RAI

NBC cam 20
NBC RF antenna
NBC/ZDF ANNOUNCE POSITION
NBC cam 18
NBC
NBC cam 8
NBC cam 15
NBC cam 10
NBC cam 1
NBC cam 16
NBC cam 14
NBC cam 14b
NBC cam 7

01_001_General Arrangement Plan_R10.dwg   revised   19 oct 2005

Scale: 1:200 @ A0

Each Black Dot
is One Node

Winter Olympics
Lighting Design: [Durham Marenghi]
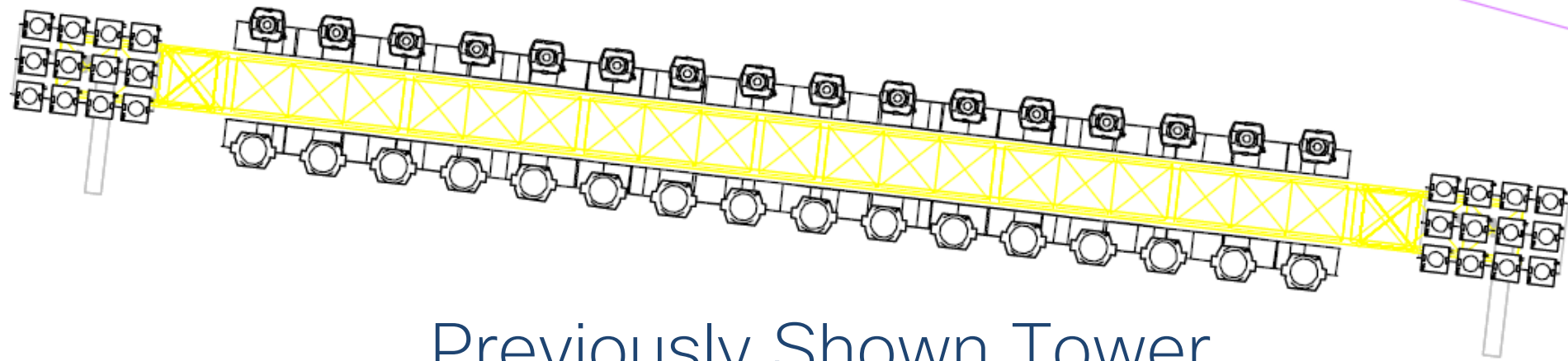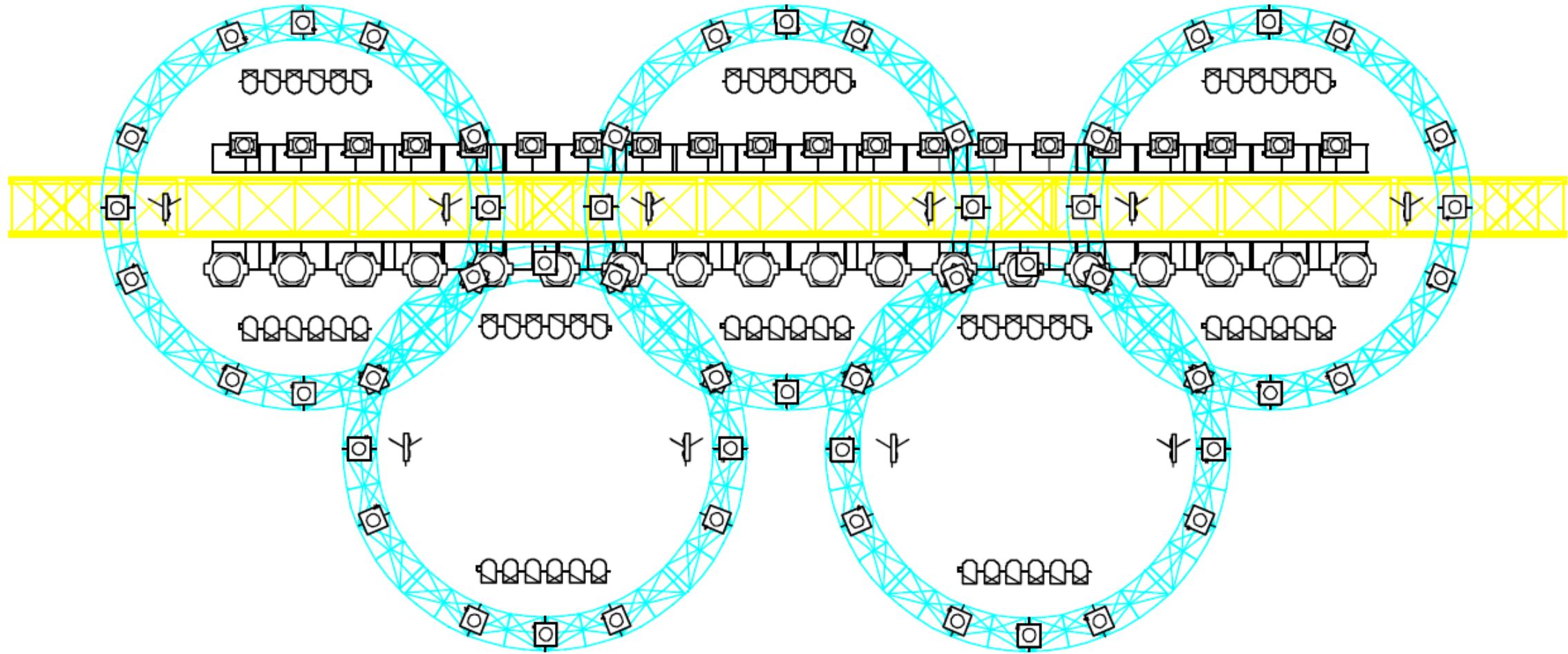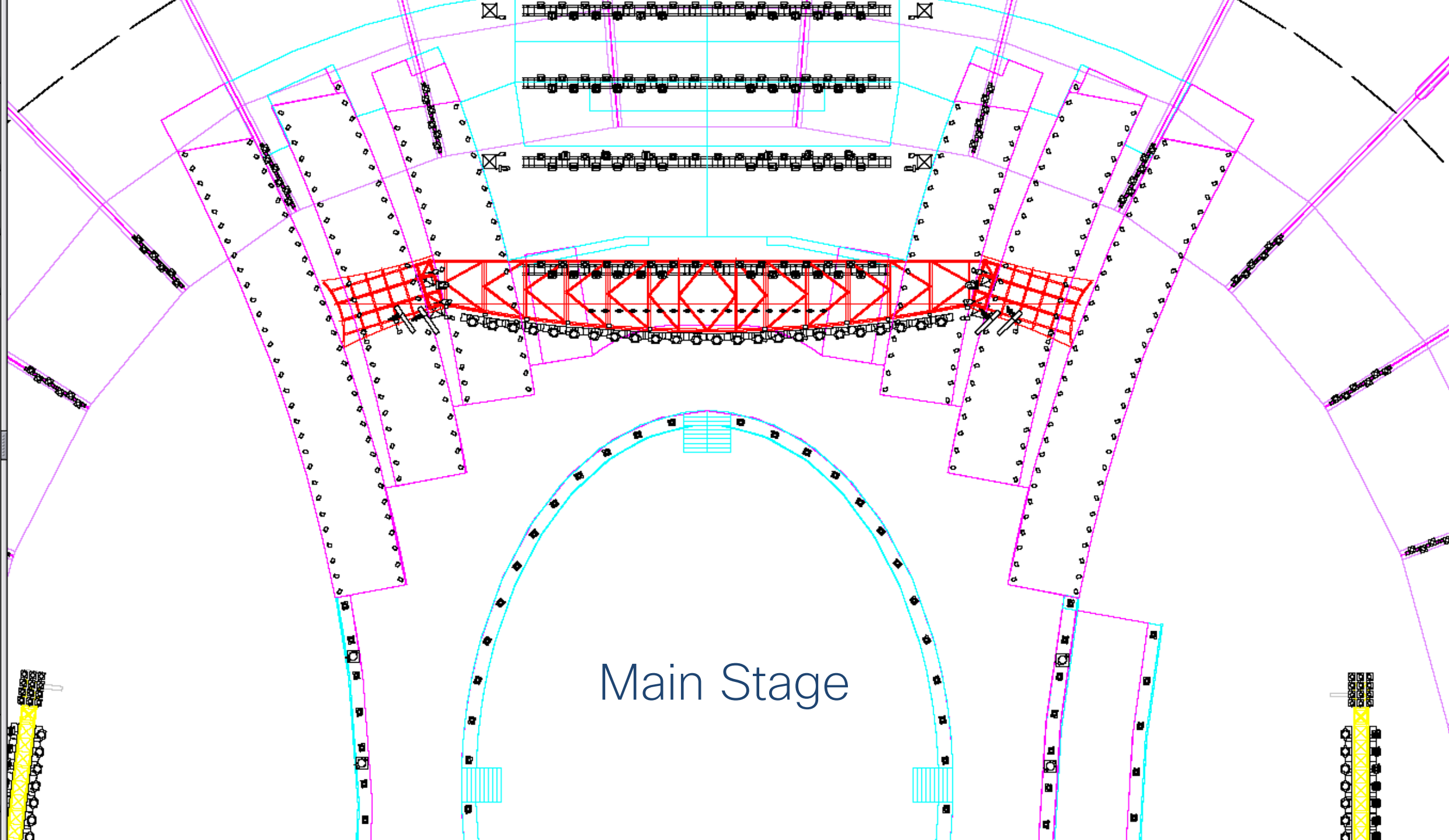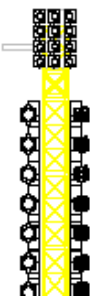
Previously Shown Tower

Largest Tower Has Nodes that Move

Main Stage

Node Schedule – 2,100 Total, None Under 100W
High power draw make PoDL impractical for all but the simplest fixtures

Stadium Roof Houselighting
240 x Coemar I wash 575EB + Rain hoods.
360 x Space Cannon Luxor R/G/B 1.2m LED Strips, 6 degree.
24 x 2kw tungsten Fresnel + Barndoors.

Side 'Gold Post' Towers (x4)
36 x MoleFay Par36 4-lamp DWE + Barndoors.
192 Space Cannon Helyos R/G/B LED Par, Clear lens Truss Toners.
8 x 2.5kw Lycian Follow Spots
64 x NEW Space Cannon 3kw Xenon Washlights/B-52s.
80 x Coemar Ispot extreme + Rain hoods.
96 x Coemar Iwash 575 EB + Rain hoods.

Stage Ramps
288 x Space Cannon Helyos R/G/B LED Pars + 12 row lenticular lenses.
96 x 1kw lamps on ramps for National Flags

Stage Side Edges
80 x Martin Mac 2000 Wash (Wide Angle) + Rain Domes or Base down
    Rain Mac.
24 x 8kw Xenon Space Cannon NEW Ireos Pro Searchlights.
50 x Martin Mac 2000 Wash (Wide Angle) + Rain Domes or Base down
    Rain Mac.

Stage End Proscenium Arch
32 x Space Cannon Helyos LED R/G/B Par Truss Toners.
32 x (2x16) Helyos R/G/B LED Par, Clear lens Truss Toners.
4 x 2.5kw Lycian Follow Spots.
24 x NEW Space Cannon 3kw Xenon Washlights/B-52s.
18 x MoleFay x Par 36 8-lamp DWE + Barndoors.

Stage End Truss Structure
180 (30 x 6-lamp bars) x Silver Par 64 1kw MFL.
80 x Martin Mac 2000 Wash + Rain hoods.
44 x Coemar Ispot extreme + Rain hoods.

Flag Pole Display
32 x Par 64 1kw MFL Floor cans (may increase by 16).
12 x 8kw Xenon Space Cannon NEW Ireos Pro Searchlights.

Other
4 x 4kw Lycian Follow Spots.

7kW "Space Cannon"

Control System

Control
- 4 x Primary Wholehog III Lighting Controllers
- 4 x Backup Wholehog III Lighting Controllers
- 21 Distributed Processors
  - 4xRS-485 Outputs Per Processor
- 51 Universes of DMX512
  - Each Universe is one 250 kbps RS-485 daisy chain
  - 23,480 8-bit Control Channels @ 30 Hz
  - **Only 5.6 Mbits Total Bandwidth!**

- Topology
  - Redundant Fiber Ring for stadium distribution
  - 10 Breakout Points
    - Ethernet to RS-485 Media Conversion Occurs Here
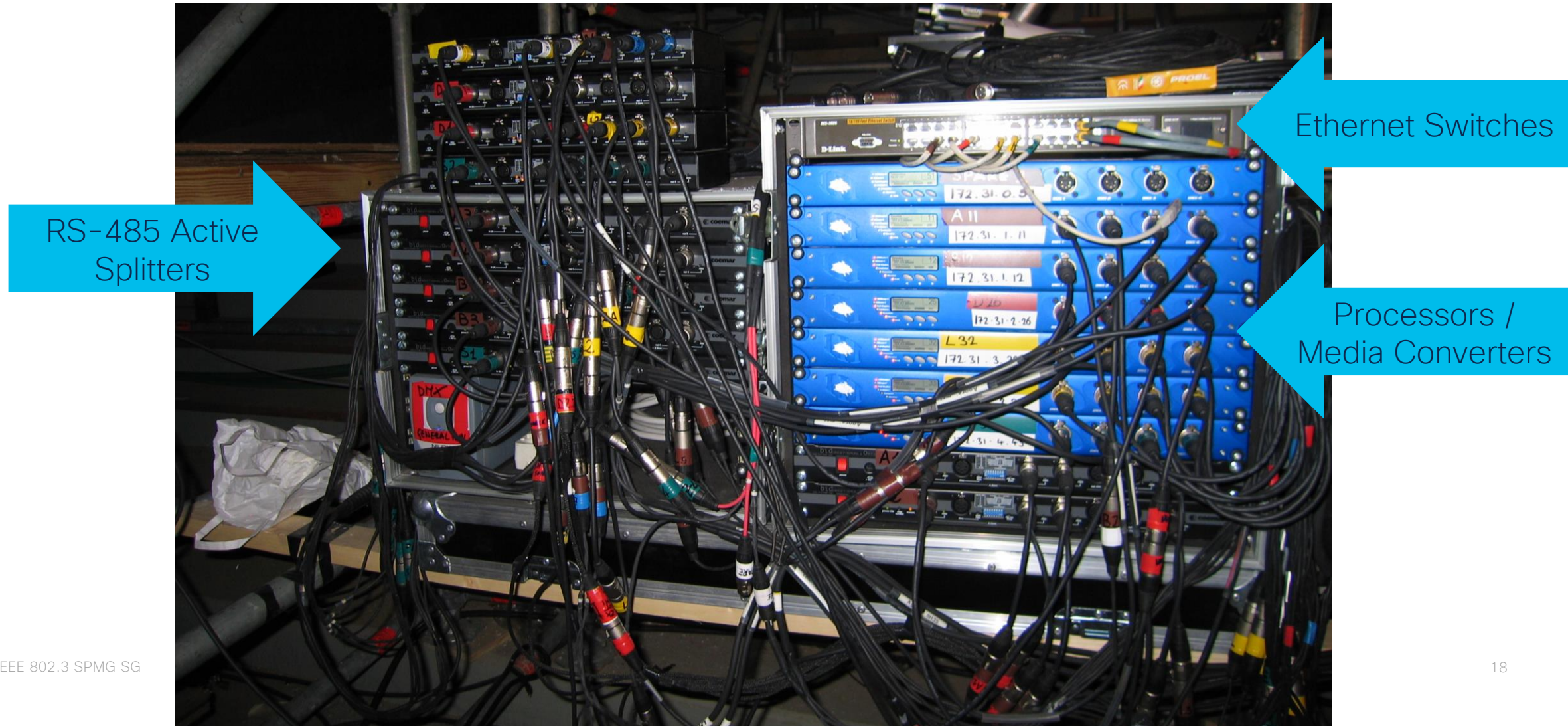 - 1 Main Control Room
  - 1 Mobile Control Room

Ethernet Network Diagram
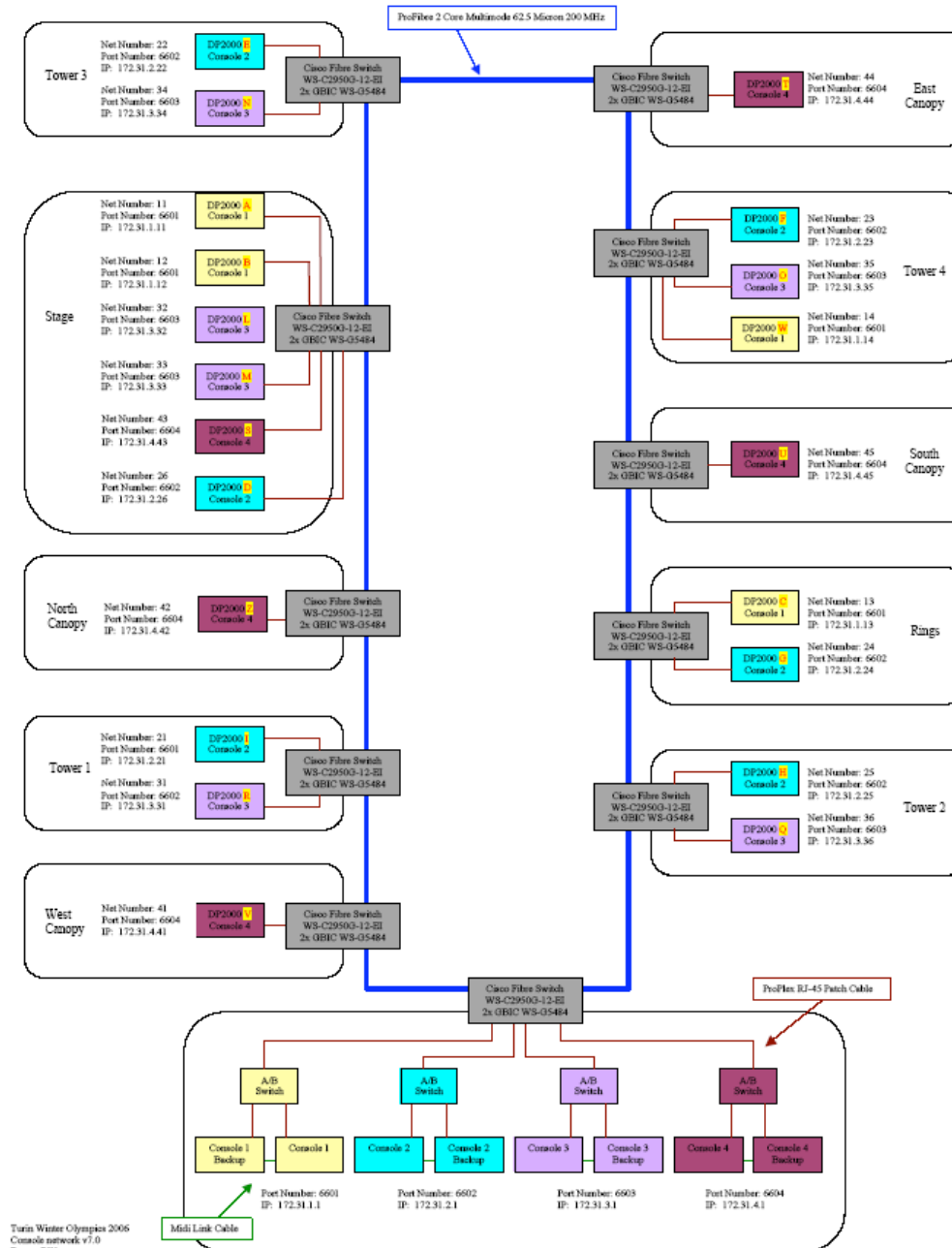
Breakout Point – Distributed Processing + Media Conversion (Ethernet to RS-485)

RS-485 Active Splitters

Ethernet Switches

Processors / Media Converters

Show

Notes on User Base

- Most users are not Electricians and are not Network Technicians
- Average High School Diploma or College Degree in Theatre Arts
- Simple rules are best
  - Any topology rules must fit on a 3x5 card
  - Most users know the "32 Nodes, 1,000 ft limit" for DMX/RS-485
  - 5-4-3 rule for Ethernet is all most users know about Ethernet
- Networks reconfigured daily, if not more often
- The Show Must Go On!
  - Delays in re-deployment are unacceptable, debugging must be fast and deterministic

Usecase: Entertainment Lighting Controls

Item	Min Value	Desired value	Extra information
Supported nodes on one mixing segment	16	32	Parity with 32-Unit load RS-485 buses preferred
Minimum supported cable length	30m	350m	1,000 ft runs are often employed in practice with up to 300 ft between nodes
Acceptable cable gauges	28 AWG – 16 AWG		22 AWG is most common for portable cabling, Cat5e for permanently installed cabling. Microphone cabling often abused for this purpose.
Required power for a node	0W	5W, 100W, 5kW	Low power only useful for media conversion. Lighting fixtures scale from watts to kilowatts, so most will have local power.
Required initial power allocation	3W	5W	Useful for performing remote diagnostics on an MCU-based device.
60V voltage OK ?	Yes		PoE frequently used in this application.
Interoperability level for the application	Plug and Play		Entire industry is based on interoperability among vendors to enable end-users to field-reconfigure the network often.
Pass through or T connection	Pass Through		Existing nodes utilize pass through connections, with active repeaters/splitters as necessary.
Hotpluggability	Critical		"The show must go on!" – network must resume operation ASAP when a bad cable or connection is fixed
Possible market (in #nodes/year)	Low Volume		Entertainment Lighting TAM is < $600M/yr, but technology spills over into architectural and broadcast markets. High visibility: Everyone knows when a major event blacks out

Presentation: <URL>

Wrap Up

- Entertainment lighting networks are real-time, and much more sensitive to disruption than architectural lighting

- Userbase and network designers are not engineers

- Power levels for nodes often exceed PoE levels, so extended multi-drop is the primary use case, not extended power

- Market is small, but technologies (such as DMX-512) get reused in architectural lighting in high volume

Item	Description
Supported nodes on one mixing segment	Indicate the numbers of nodes on a single mixing segment. The minimum reflects the number of nodes needed for the usecase to make sense. The desired value represents a natural fit for the application. Both numbers could be the same.
Minimum supported cable length	Is the length you need between the two furthest nodes on the mixing segment.
Acceptable cable gauges	What cable gauges can be accepted for the application (consider cost, size, bend radius, …)
Required power for a node	How much power is needed in the node to run the application. This is the power level as measured at the connector of the device. Note that there may be a rectifier or other elements that cause some loss (2% to 5% typical).
60V voltage OK ?	Is it acceptable for the input voltage to be up to 60V ? If not, what is the reason ?
Required initial power allocation	Because this is a bus powered system, a node needs to be permitted to draw some amount of power after being plugged in. This power is used to communicate with the PSE about the power requirements. The system should be able to operate it's PHY with this power. How much power do you foresee to need for this. This is different from the "Required power for a node" which is about the complete power need of the device.
Interoperability level for the application	Choose between "plug&play" or "engineered" system. Plug & play means that a compliant device works when connected to a network of other compliant devices. There is no need for configuration or to verify if devices will be compatible or not. Engineered system means that you will use the standard within your own products or that the end user can determine which devices will work in the system.
Pass through or T connection	See slide 4-6 of http://grouper.ieee.org/groups/802/3/SPMD/public/sep19/spmd_cjones_01_0919.pdf If the application cannot be equipped with two connectors, select T connection. If it must be possible to live connect a new node without disconnecting other nodes, also select T connection.
Hotpluggability	Should it be supported to connect new devices while the bus is powered and guaranteed that this does not cause devices to be interrupted (eg. Reboot, lose long stretches of data). If not required, select no.
Possible market size	Potential market expressed in number of nodes. Do not express this in currency of any kind due to IEEE SA rules.