

IPv4 Address Lifetime

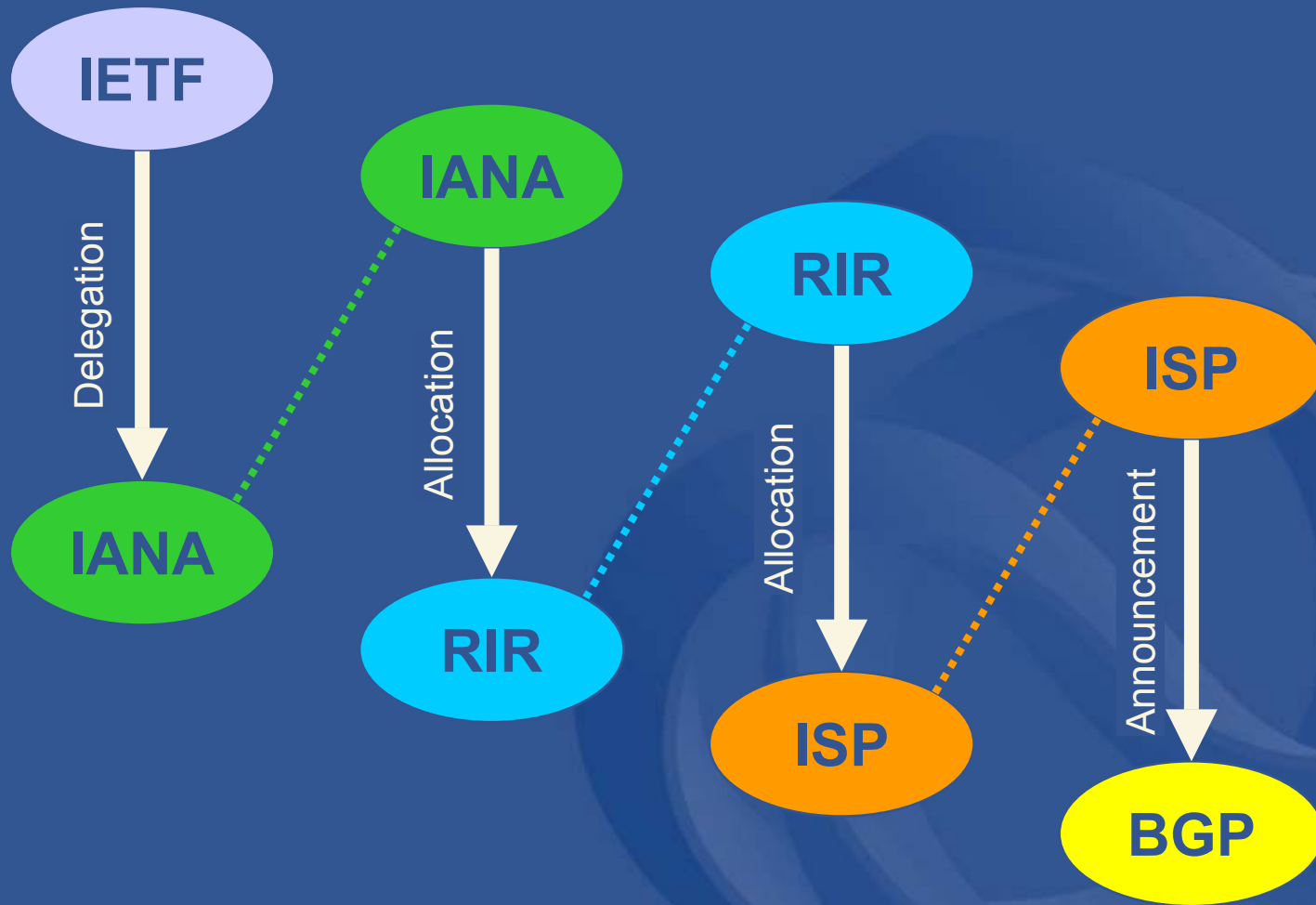
**Presented by
Paul Wilson, APNIC**

**Research activity
conducted by Geoff Huston
and supported by APNIC**

IPv4 Address Lifetime

- Early 90's: IETF activity - Routing and Addressing (ROAD) group
 - Objective: to understand the rate of allocation of IPv4 addresses, and predict the date of eventual exhaustion of the unallocated pool
 - Prediction: the pool of IPv4 addresses would be exhausted around 2008-2011
- This is a re-visiting of that activity considering latest data, including...
 - IANA and RIR delegations
 - ISP announcements to the BGP routing table

Address Management Process



Modeling the Process

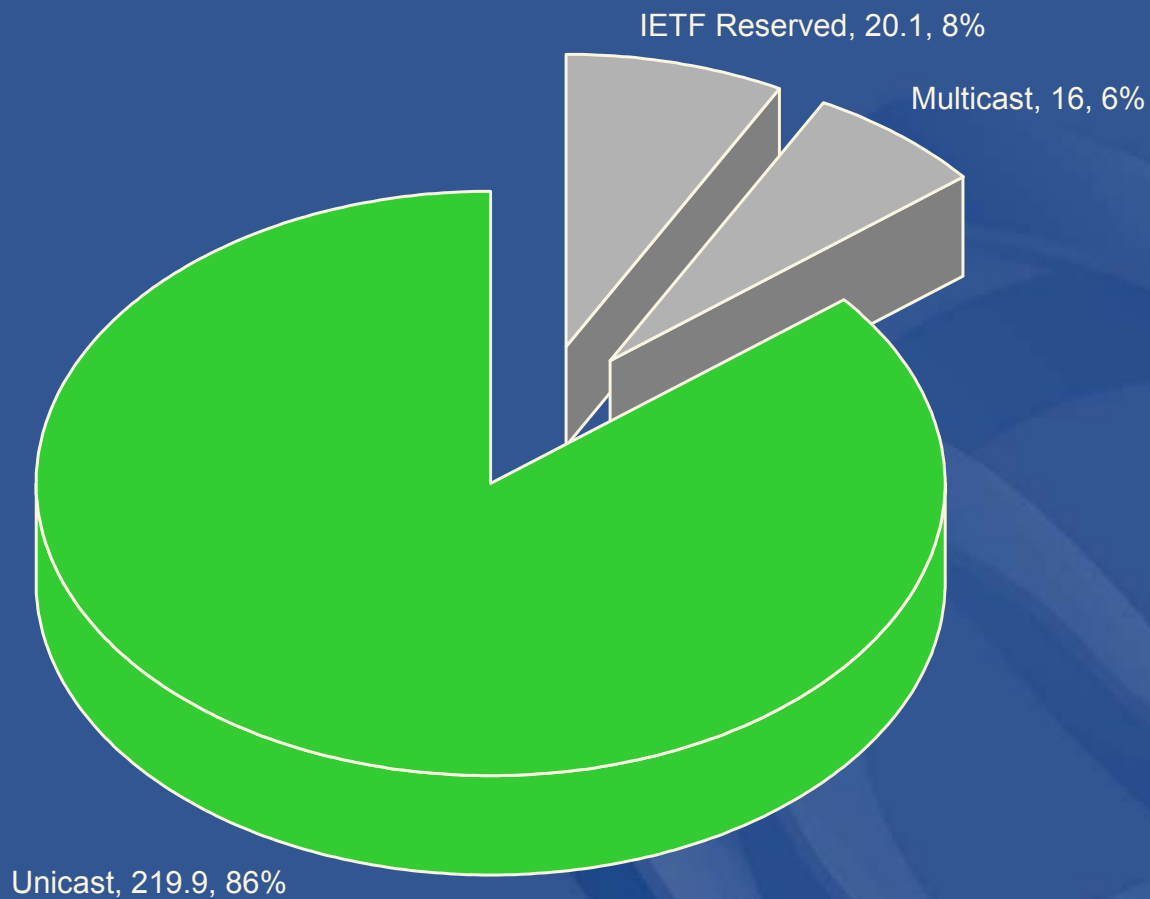
1. IETF definition of IPv4
 - Data source: IETF standards (RFCs)
2. IANA allocations to RIRs
 - Data source: IANA IPv4 Address Registry
3. RIR allocations to ISPs
 - Data source: RIR Stats files
4. ISP announcements
 - Data source: BGP routing table
 - Updated in latest work presented here

1. IETF Delegations

IPv4 Address Space

- Defined by the IETF
 - 32 bits providing 4G addresses
- The IETF has defined space for global unicast and for other purposes
- Responsibility for global unicast address space is delegated to the IANA
 - Total 220/256 blocks available (88%)
- IANA allocates space to the RIRs for further allocation and assignment

IPv4 Address Space



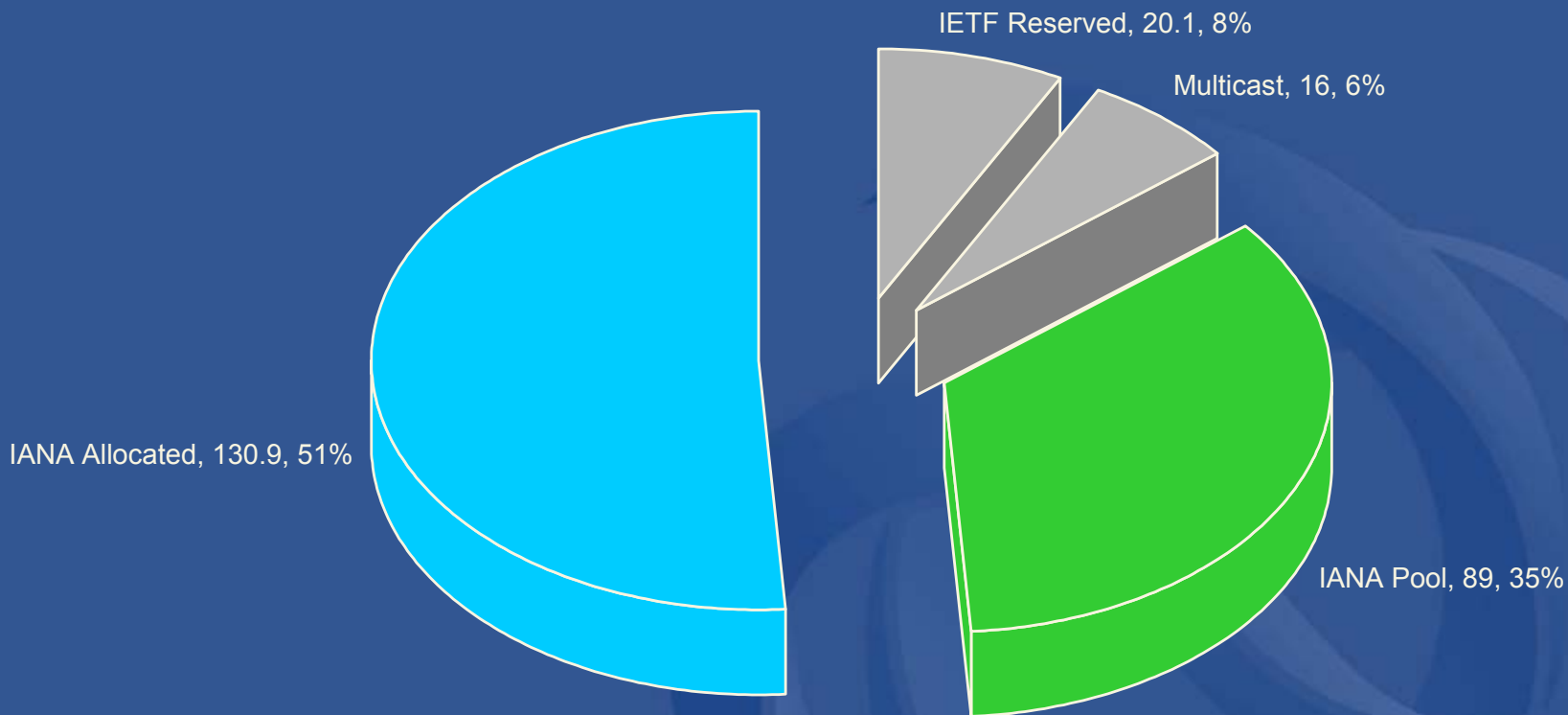
by /8 block equivalents

2. IANA Allocations

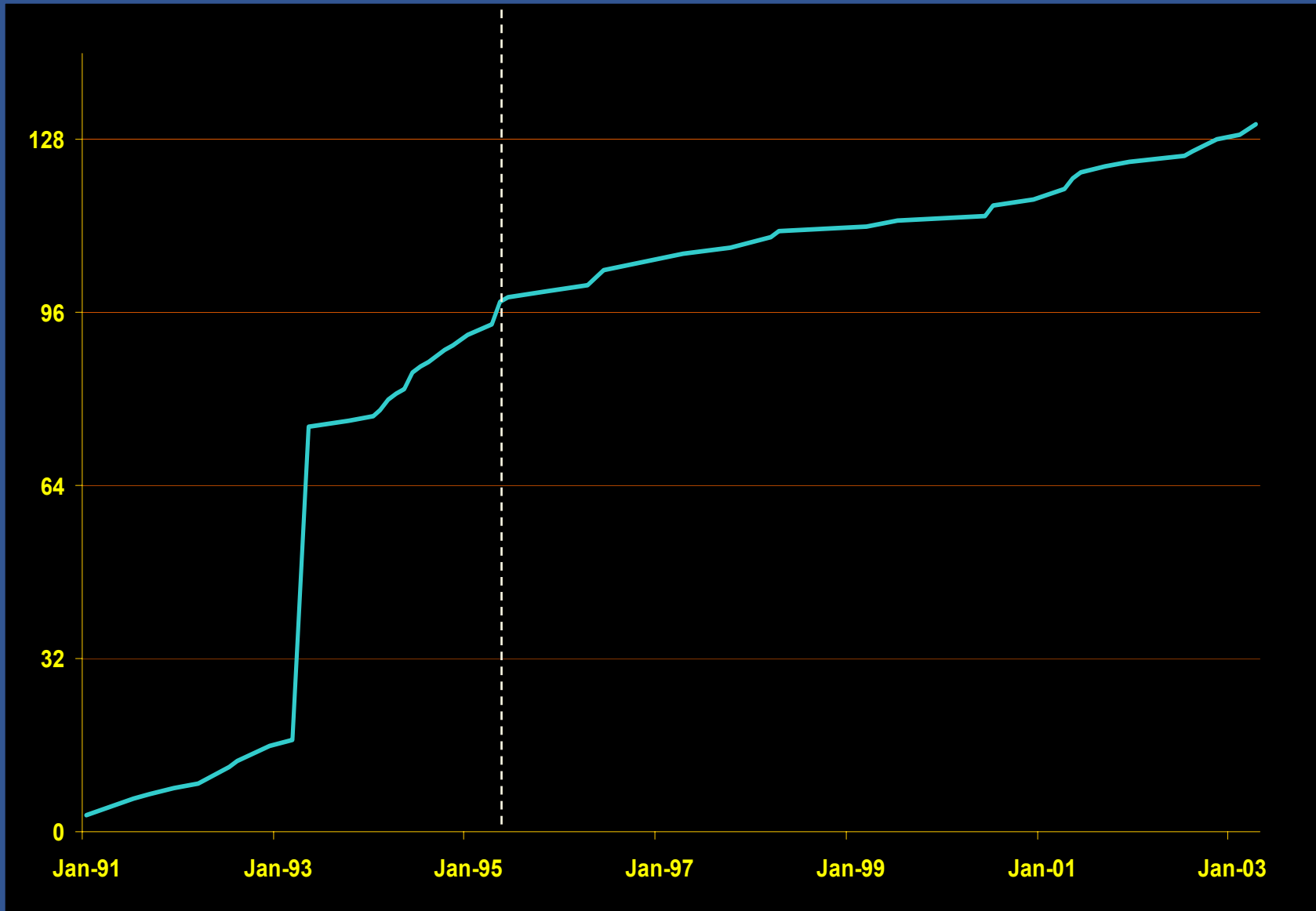
IANA Allocations

- IANA allocates address space to RIRs
 - Progressively as required
- The IANA IPv4 address registry records the date of each /8 allocation undertaken by the IANA
- This data has some inconsistencies
 - Due to changing IANA administration and practices over many years
- However recent data is stable enough to allow projection

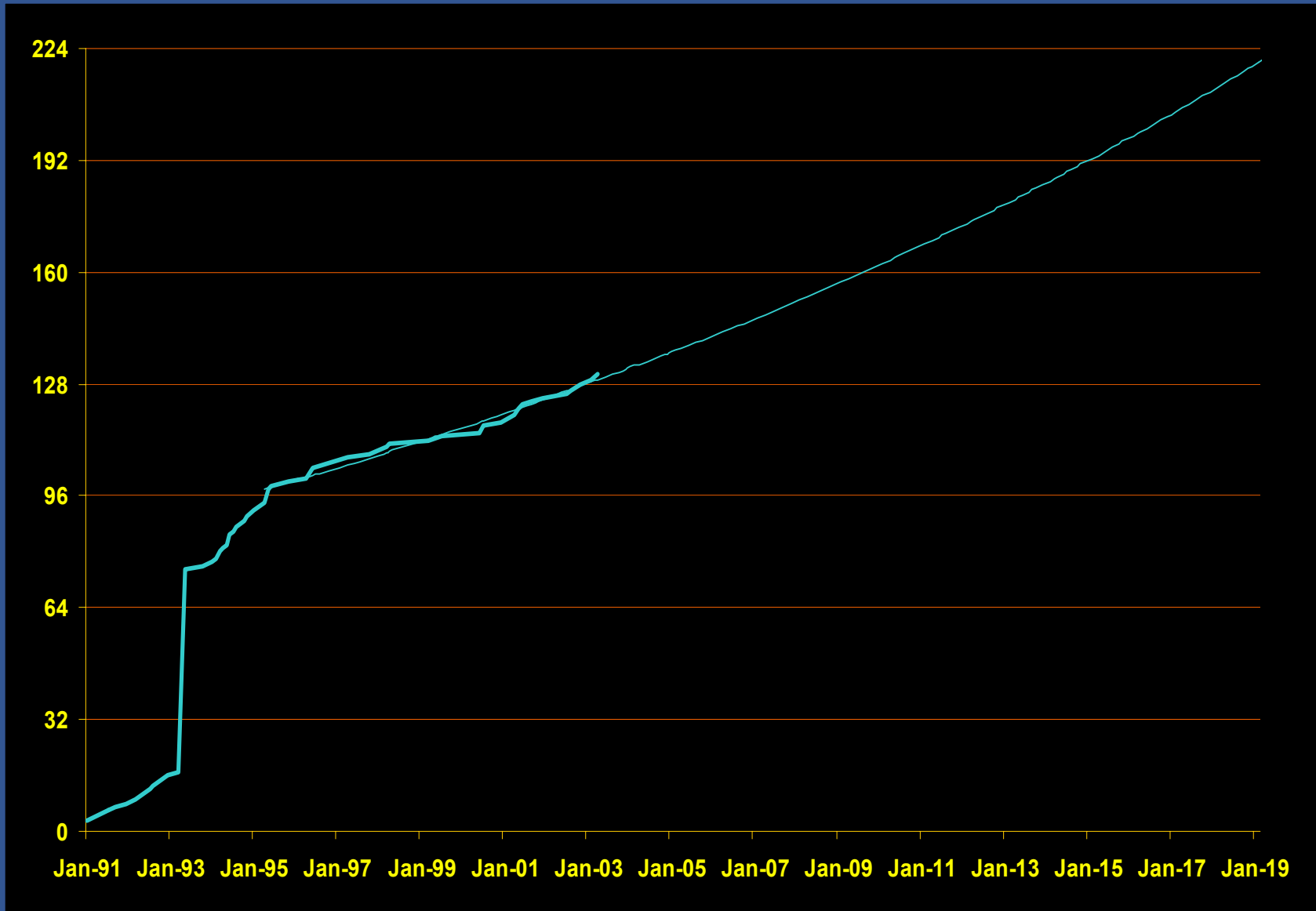
IANA Allocations - Current



IANA Allocations - Historical



IANA Allocations - Projection



IANA Allocations - Projection

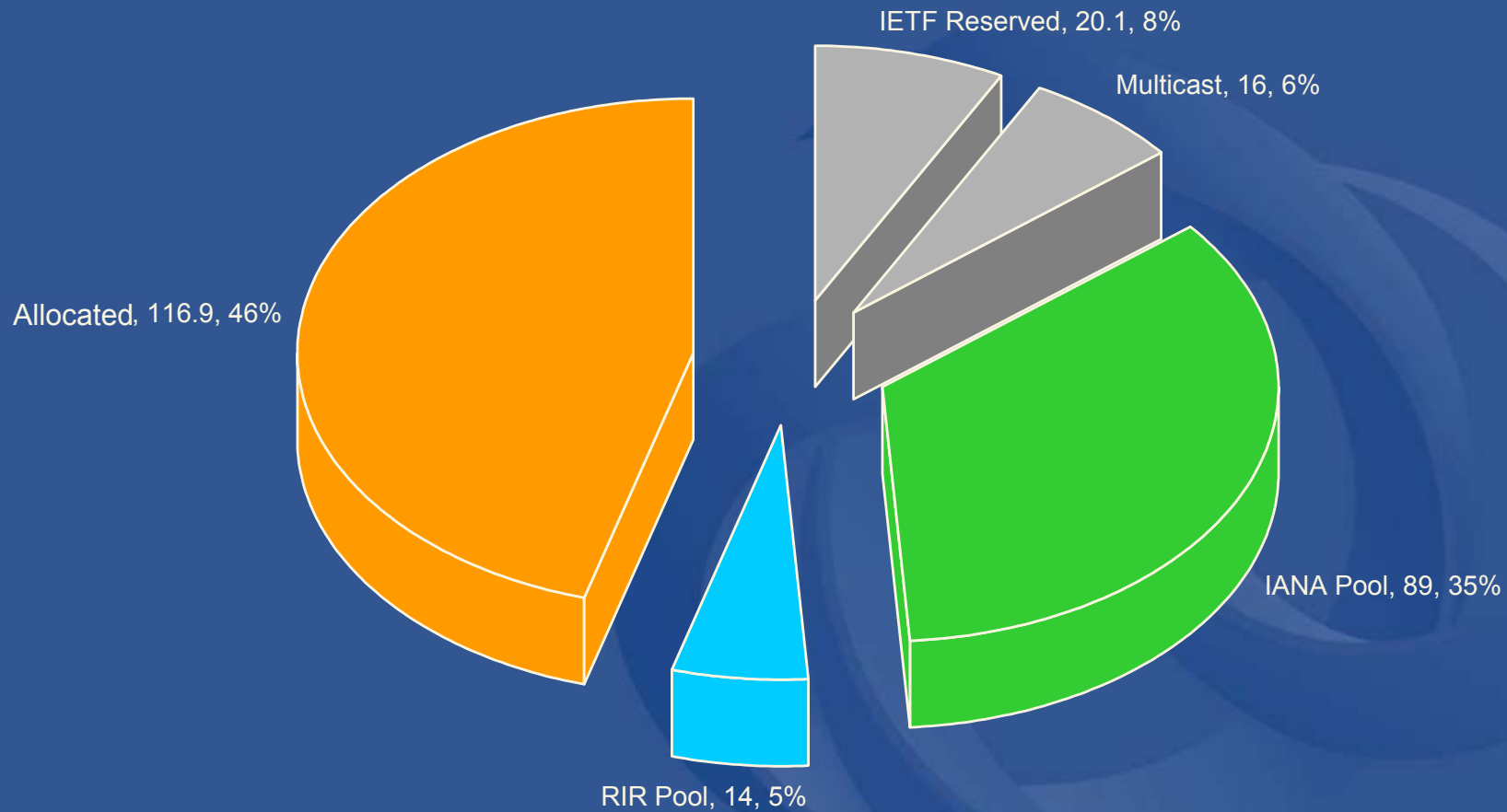
- Projected date of IANA address pool exhaustion: 2020
- This projection is very uncertain due to:
 - Sensitivity of allocation rate to prevailing RIR allocation policies
 - Sensitivity to any significant uptake up of new applications that require public addresses

3. RIR Allocations

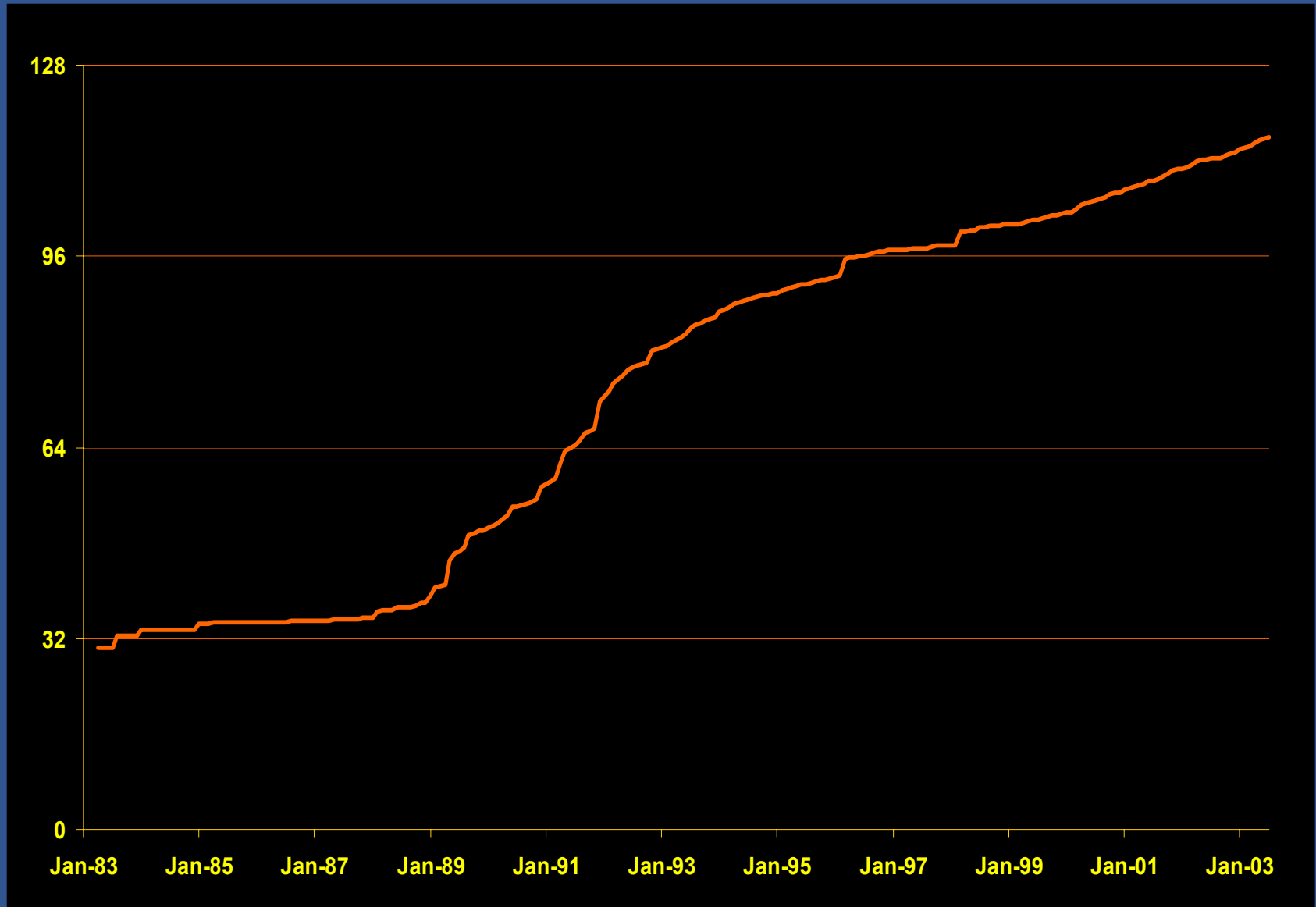
RIR Allocations

- RIRs allocate address space to LIRs (ISPs)
- RIR stats files records the date of each allocation to an LIR, together with the allocation details
- Analysis of allocations includes RIR and IANA

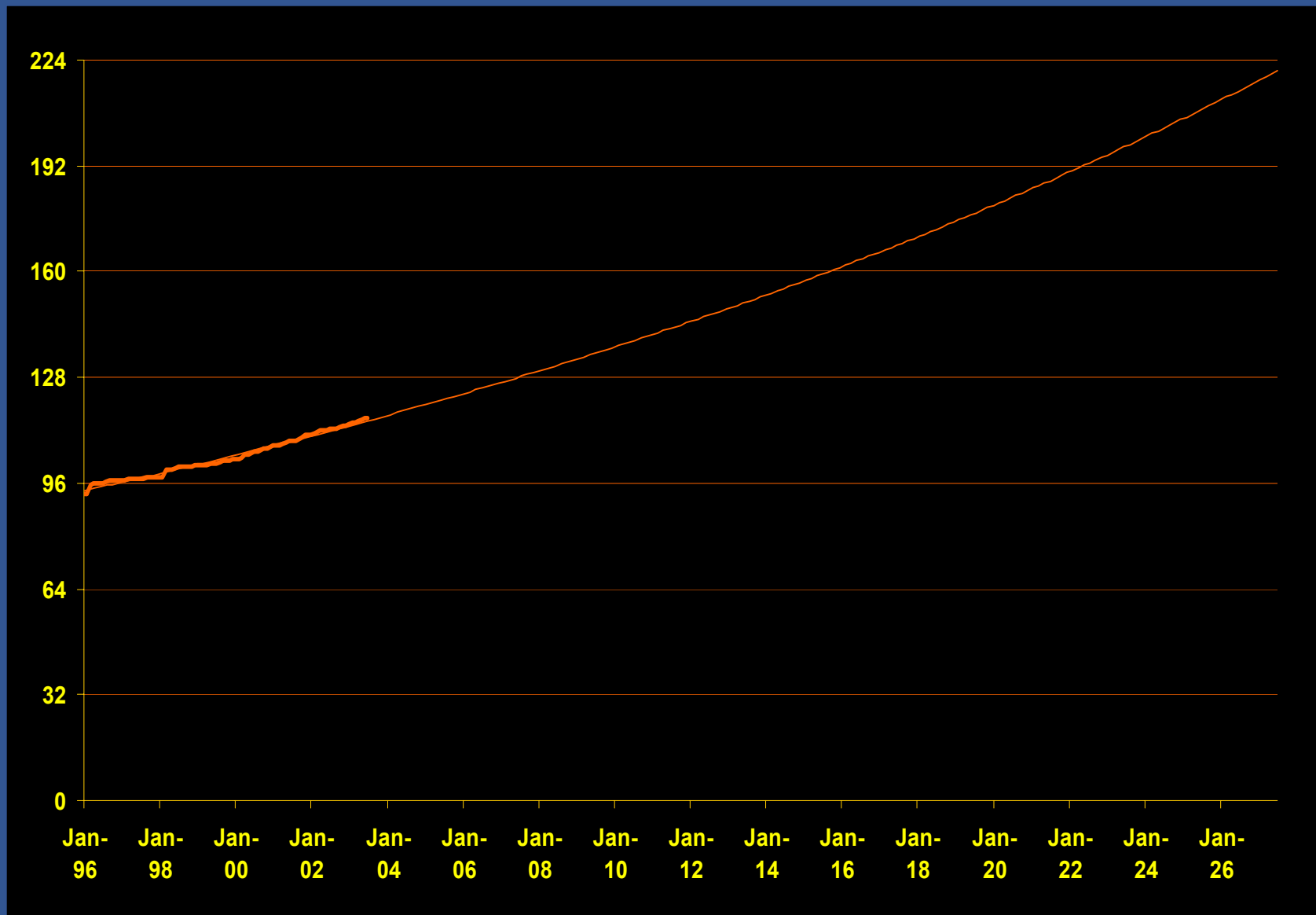
Total Allocations - Current



Total Allocations - Historical



Total Allocations - Projection



Total Allocations - Projection

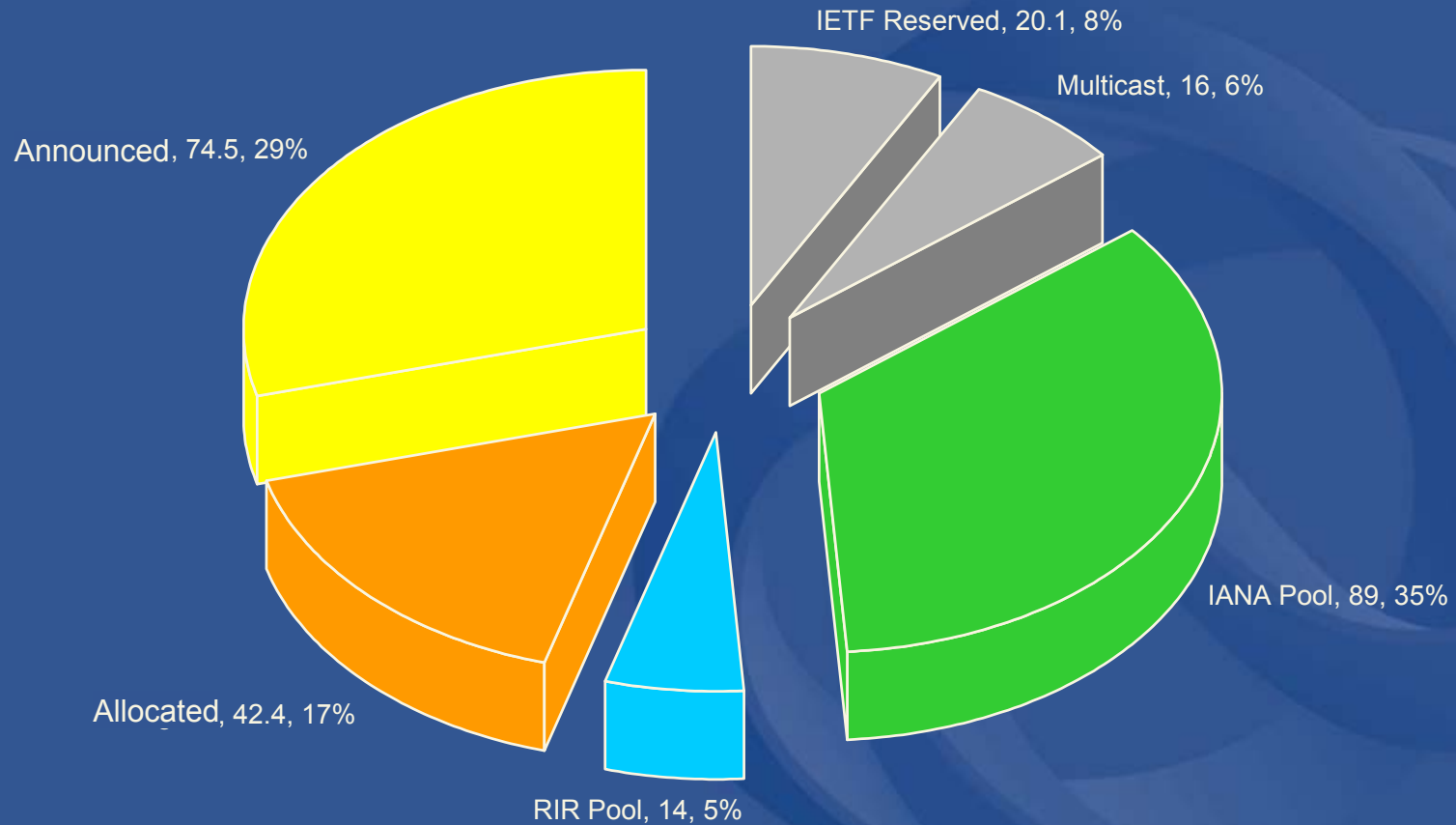
- Projected date of RIR address pool exhaustion: **2027**
- The projection has the same levels of uncertainty as noted for the IANA projections:
 - RIR management policies
 - Technological developments

4. BGP Routing Table

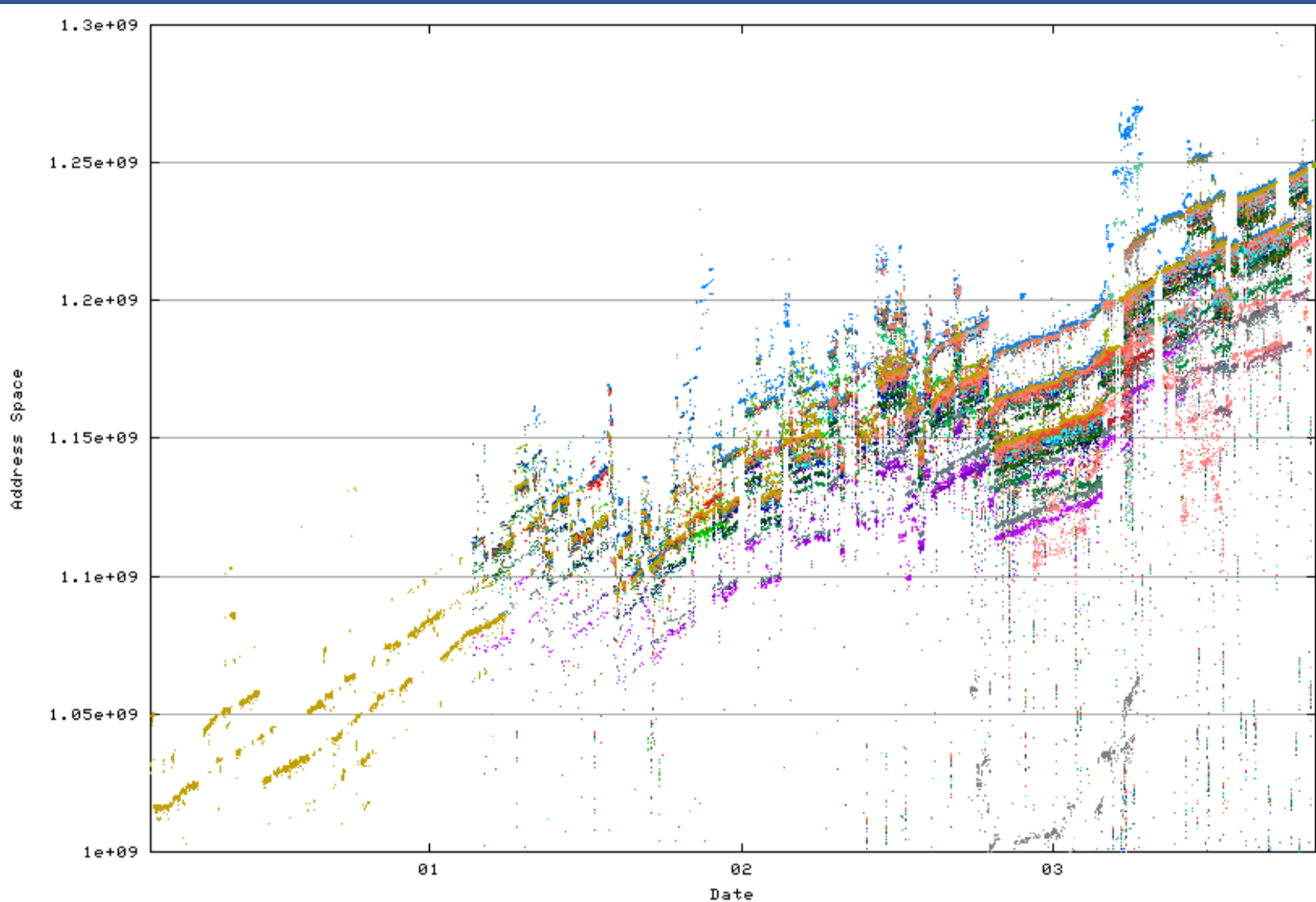
BGP Routing Table

- The BGP routing table spans a set of advertised addresses
 - Representing addresses in use by ISPs
- A similar analysis of usage and projection can be undertaken on this data
- Assumption: BGP routing table represents actual IP address usage
 - Therefore it “drives” the other trends

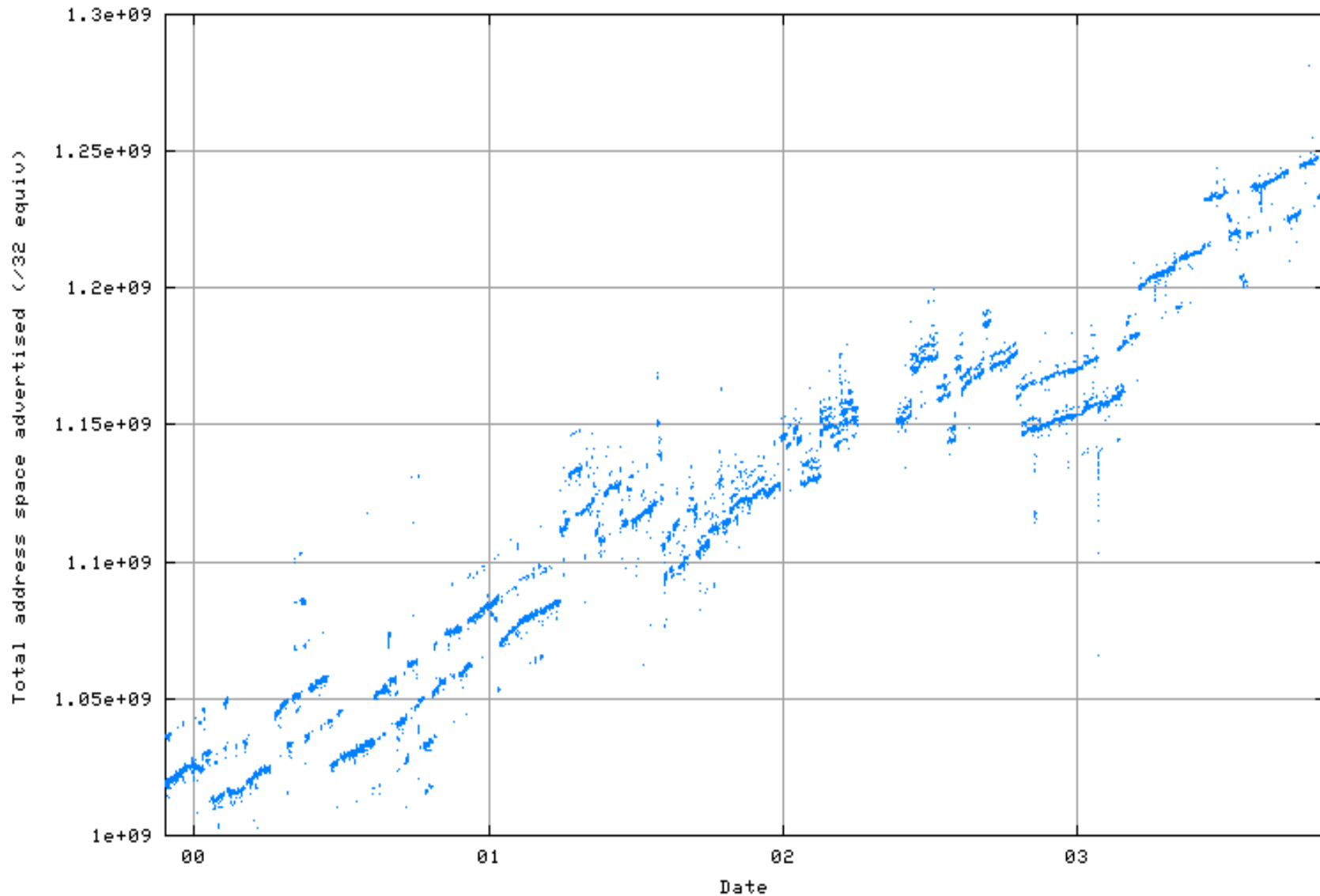
BGP Routing Table - Current



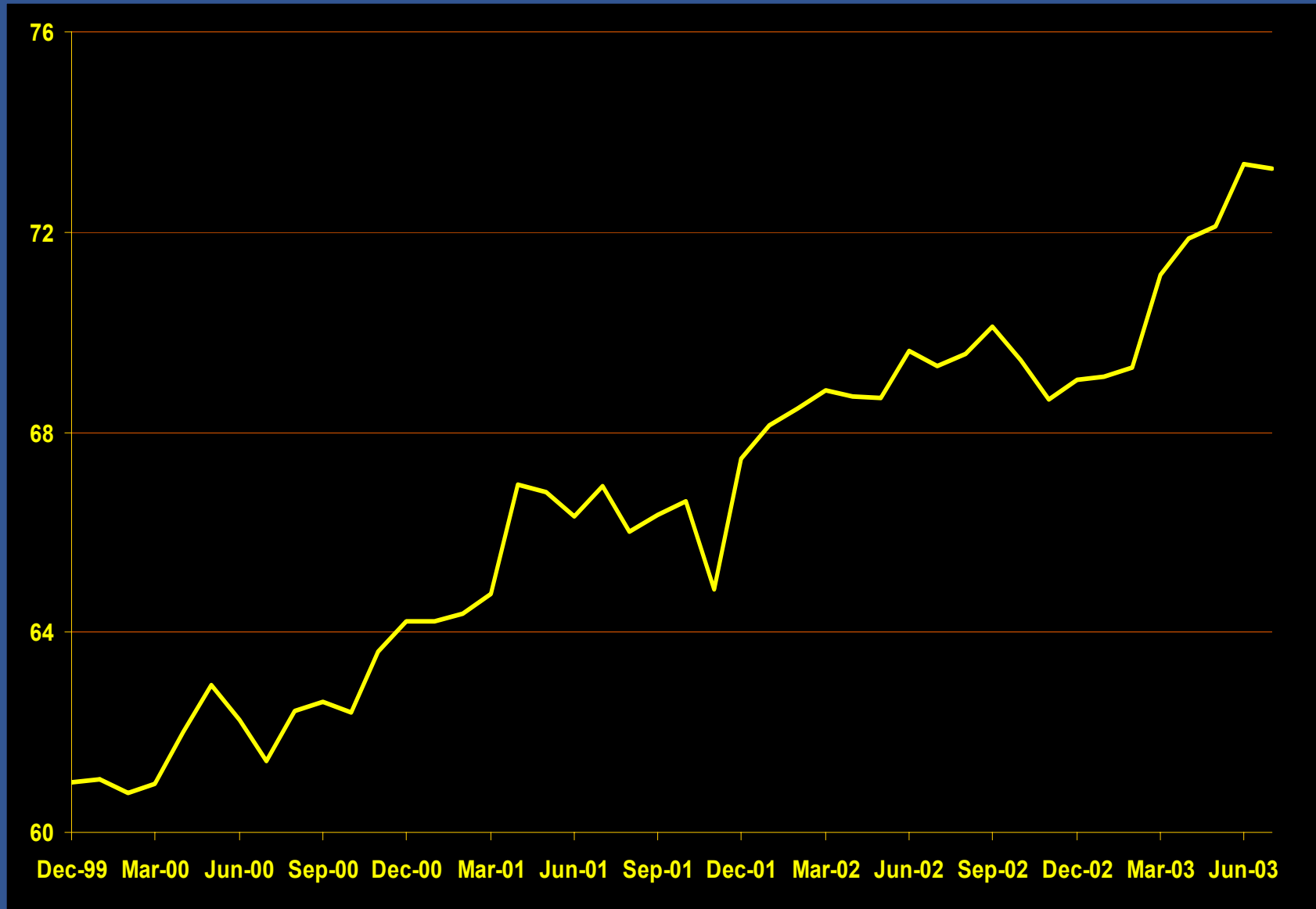
BGP Routing Table - routeviews



BGP Routing Table - AS1221



BGP Announcements - Historical



BGP Announcements - Projection



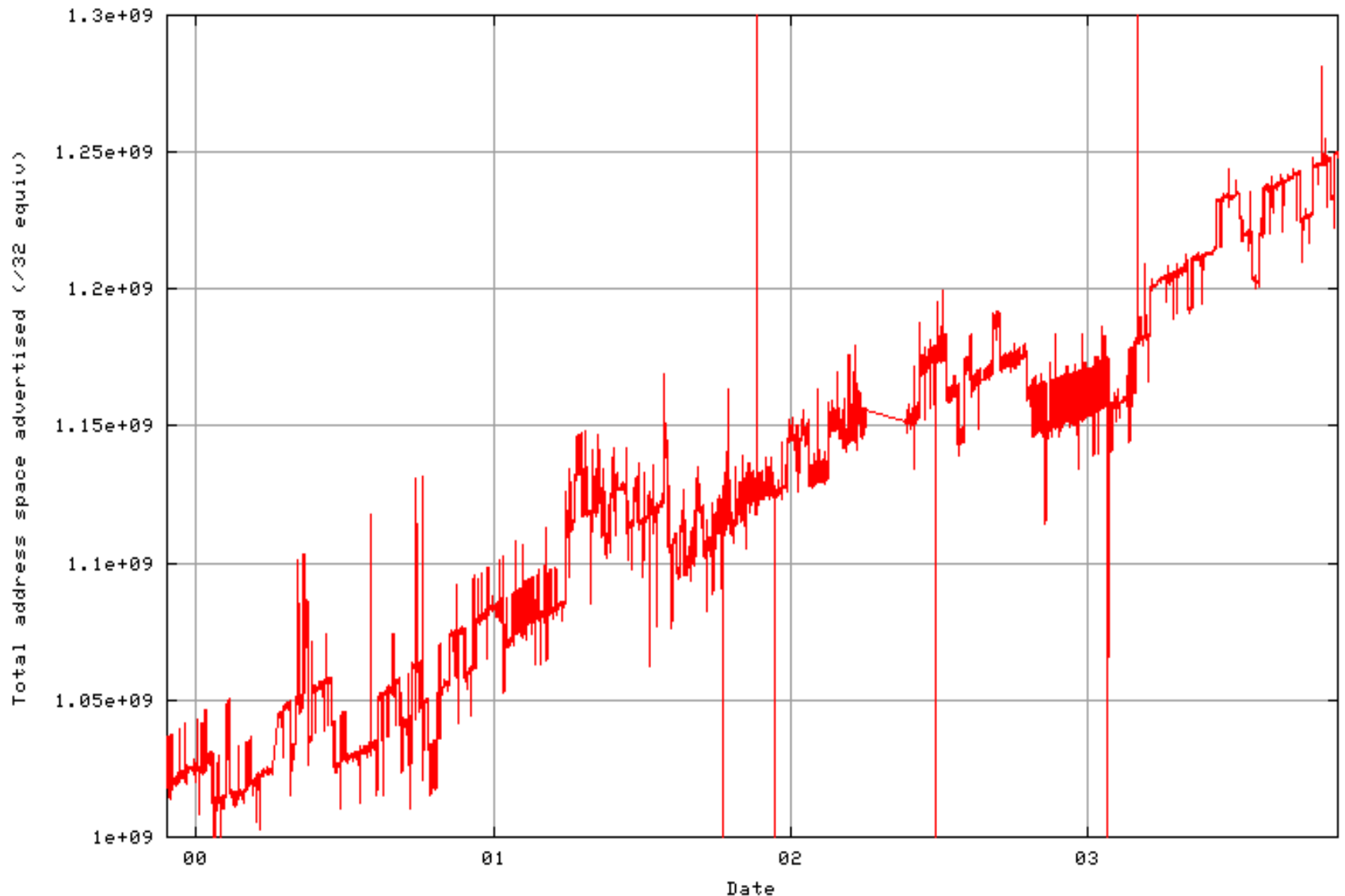
BGP Announcements - Projection

- Projected date of address pool exhaustion according to BGP: **2026**
- This projection uses a 3 year data baseline to obtain the projection
 - This is much shorter baseline than the IANA and RIR projections
 - There are, again, considerable uncertainties associated with this projection

BGP Projections - Revisited

- Comments received about this projection have prompted a more detailed analysis of the BGP data
- It appears that there is a different view that can be formed from the data
- Firstly, here's the raw data – hourly measurements over 3 years...

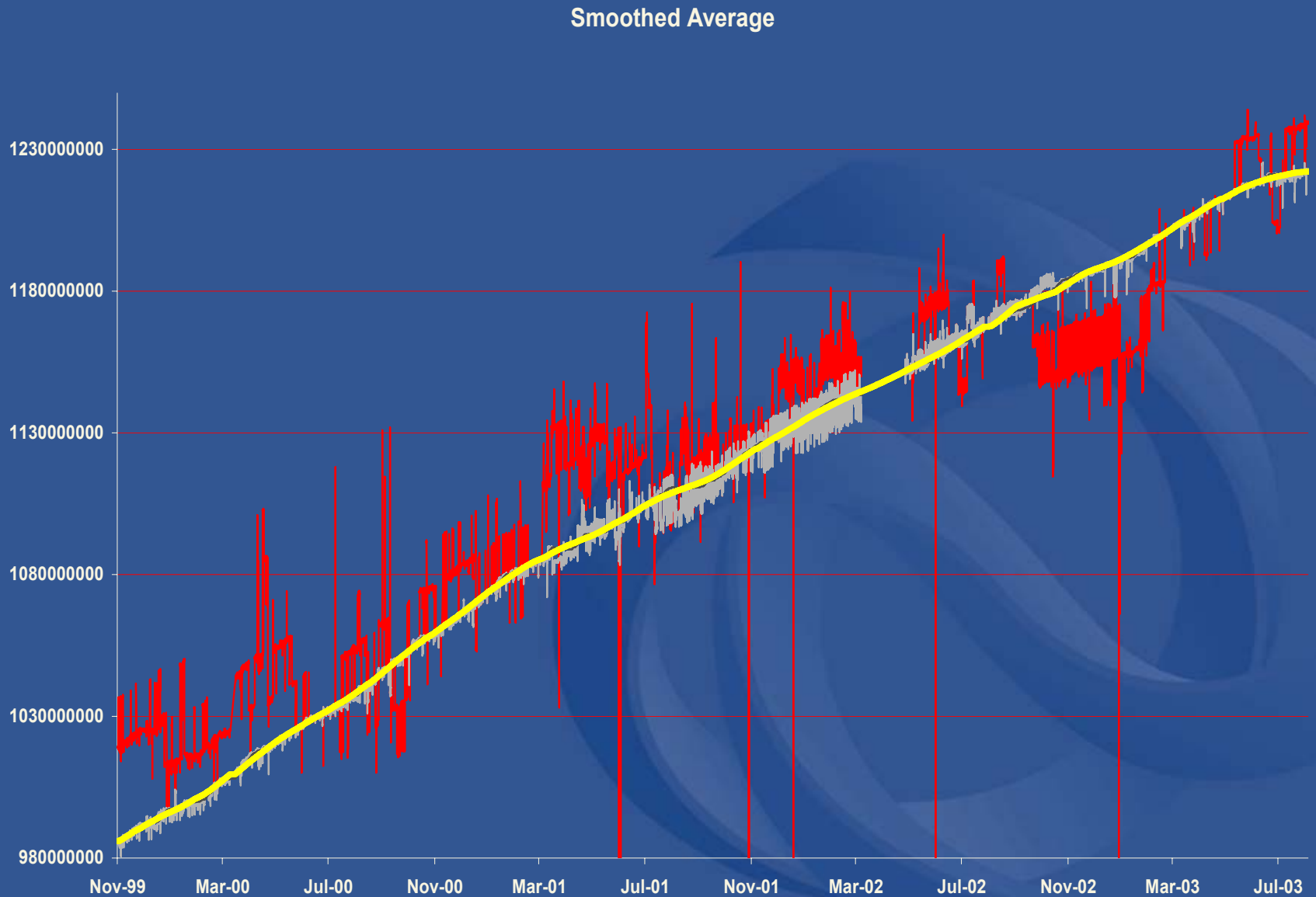
Another look at that BGP data...



Another look at that BGP data...

- The most obvious noise comes from flaps in /8 advertisements
- The first step was to remove this noise from the source data
 - By recalculating the address data assuming a fixed number of /8 advertisements
 - The value of 19 was used to select one of the 'tracks' in the data
- Next use gradient limiting and sliding average to smooth the data

Another look at that BGP data...

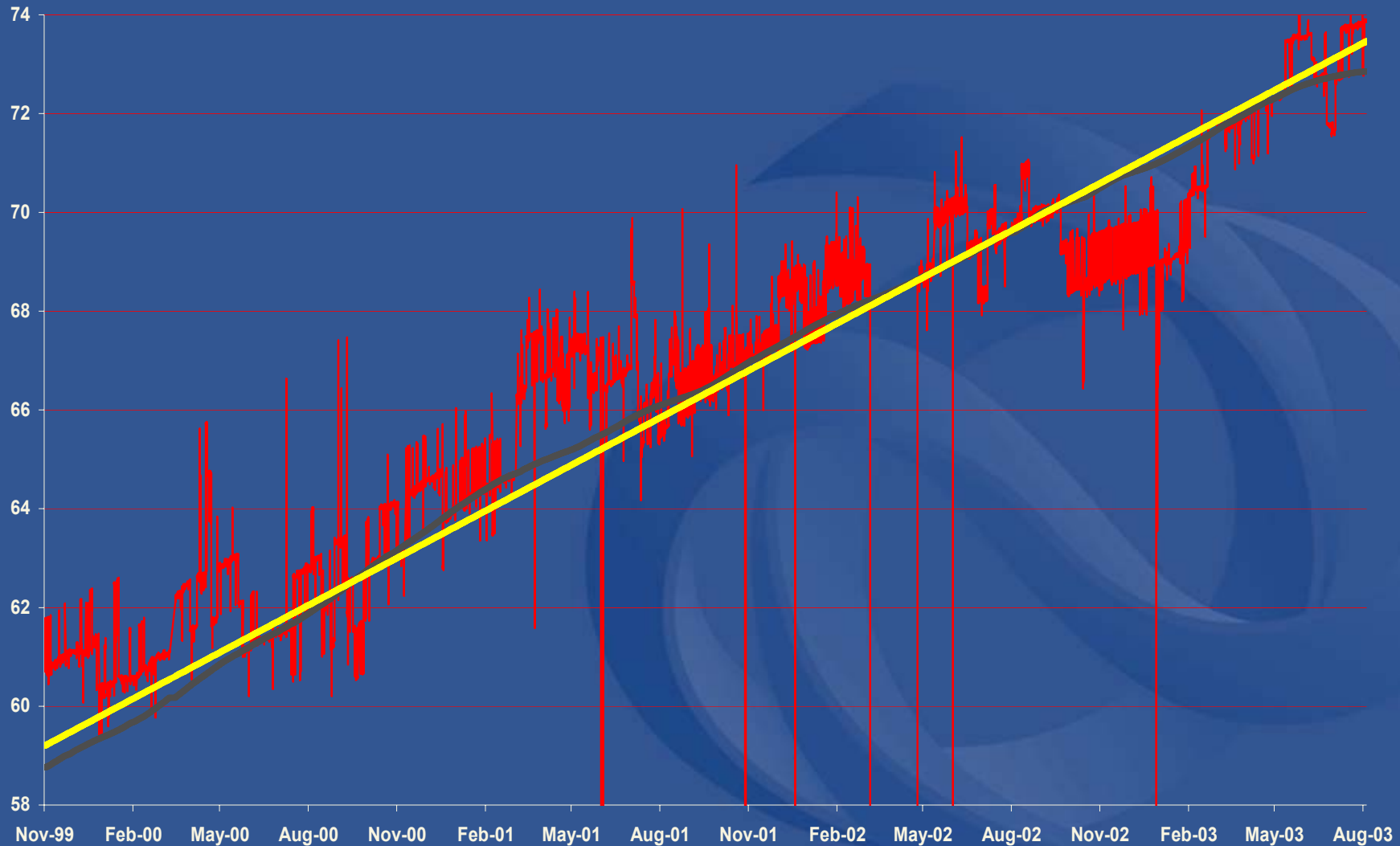


Another look at that BGP data...

- Its now possible to apply a best fit function to the data.
- A linear model appears to be the most appropriate fit:...

Another look at that BGP data...

Linear Squares Best Fit

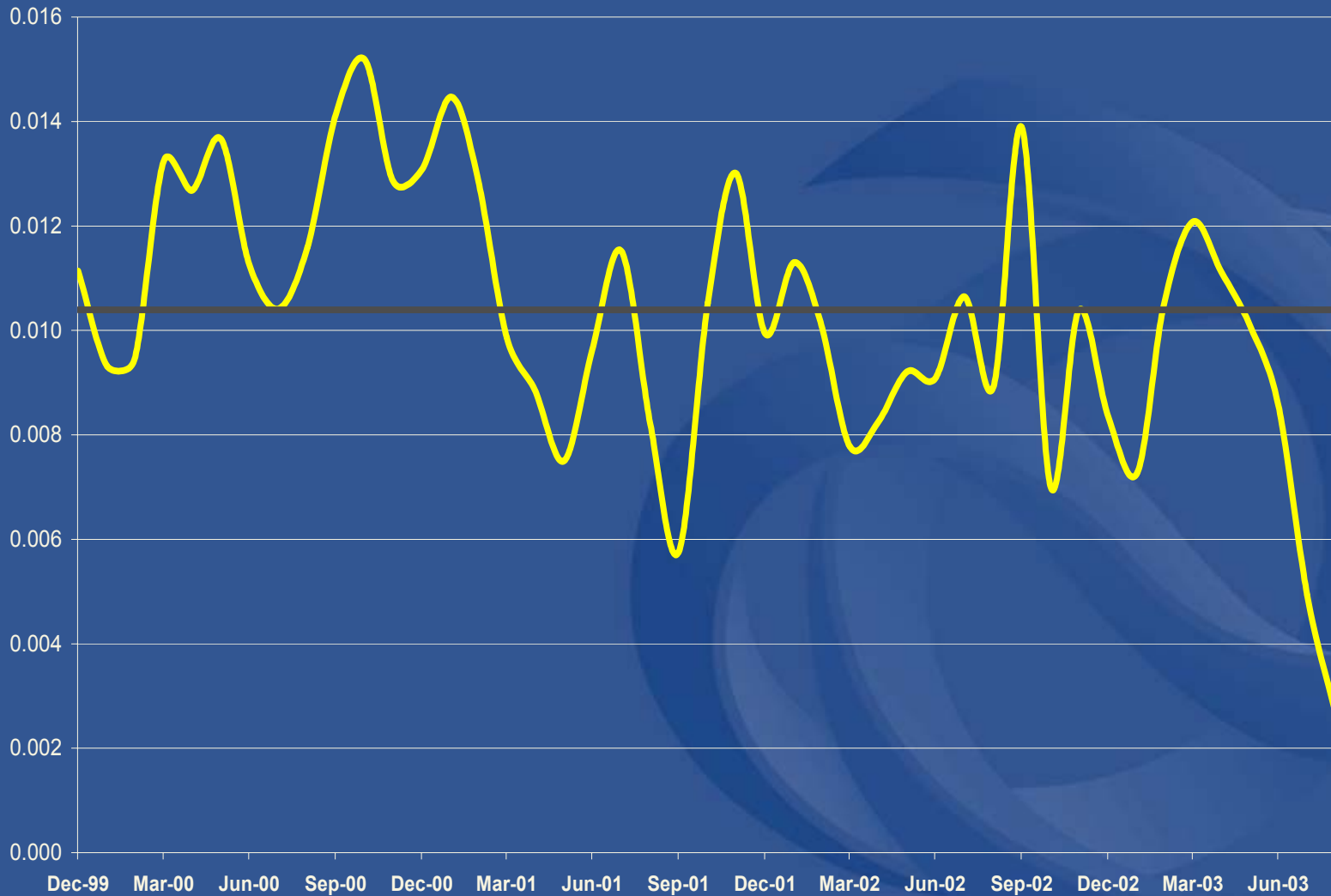


Another look at that BGP data...

- Is linear fit appropriate?
- First order differential of total BGP announcement
 - Until 2000, exponential (accelerating) growth
 - Since 2000, oscillating differential and overall deceleration
 - Last 6 months, differential approaching 0 (i.e. no growth)
- Linear fit seems most appropriate for this data

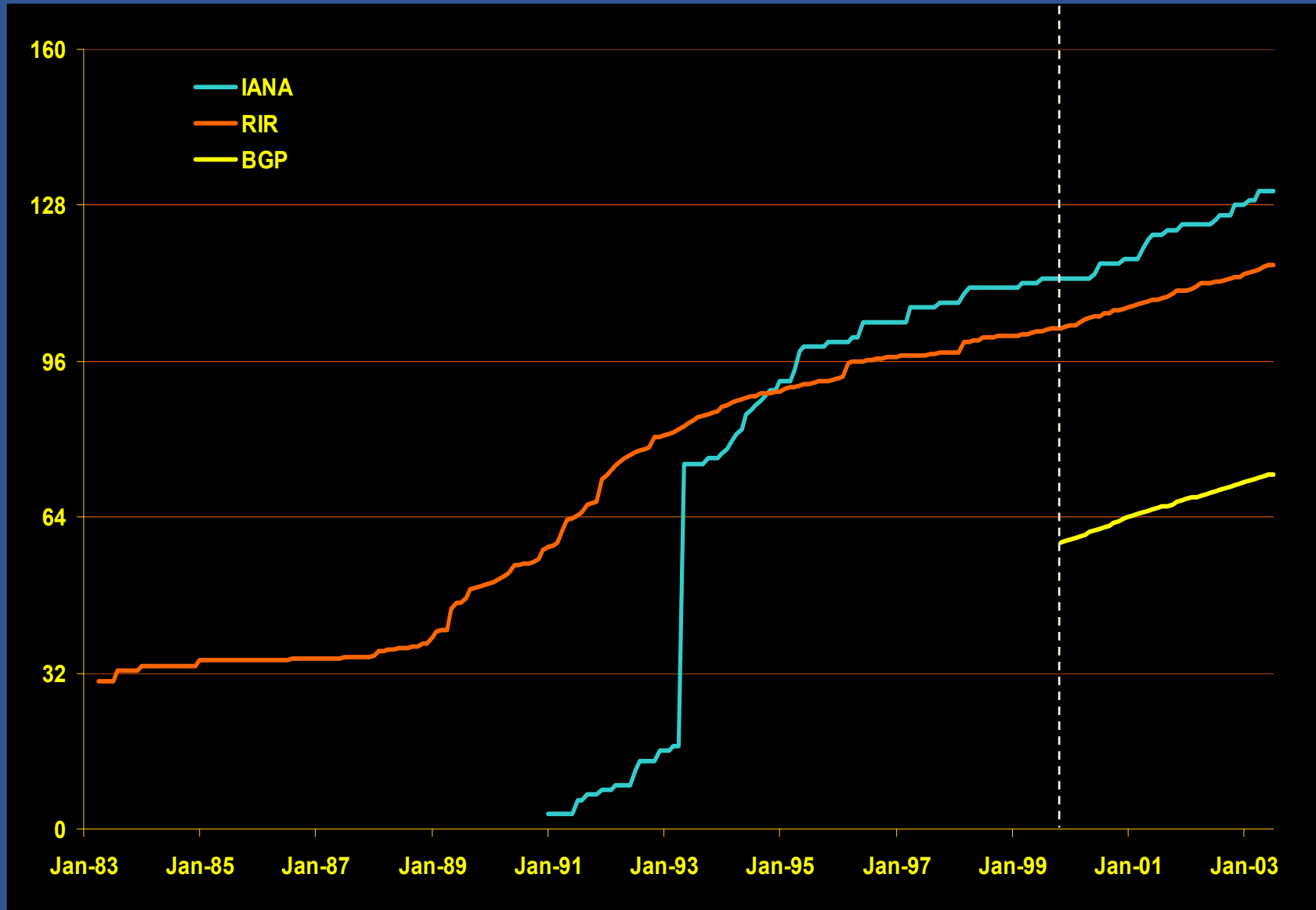
Another look at that BGP data...

daily rate of change in address growth per month

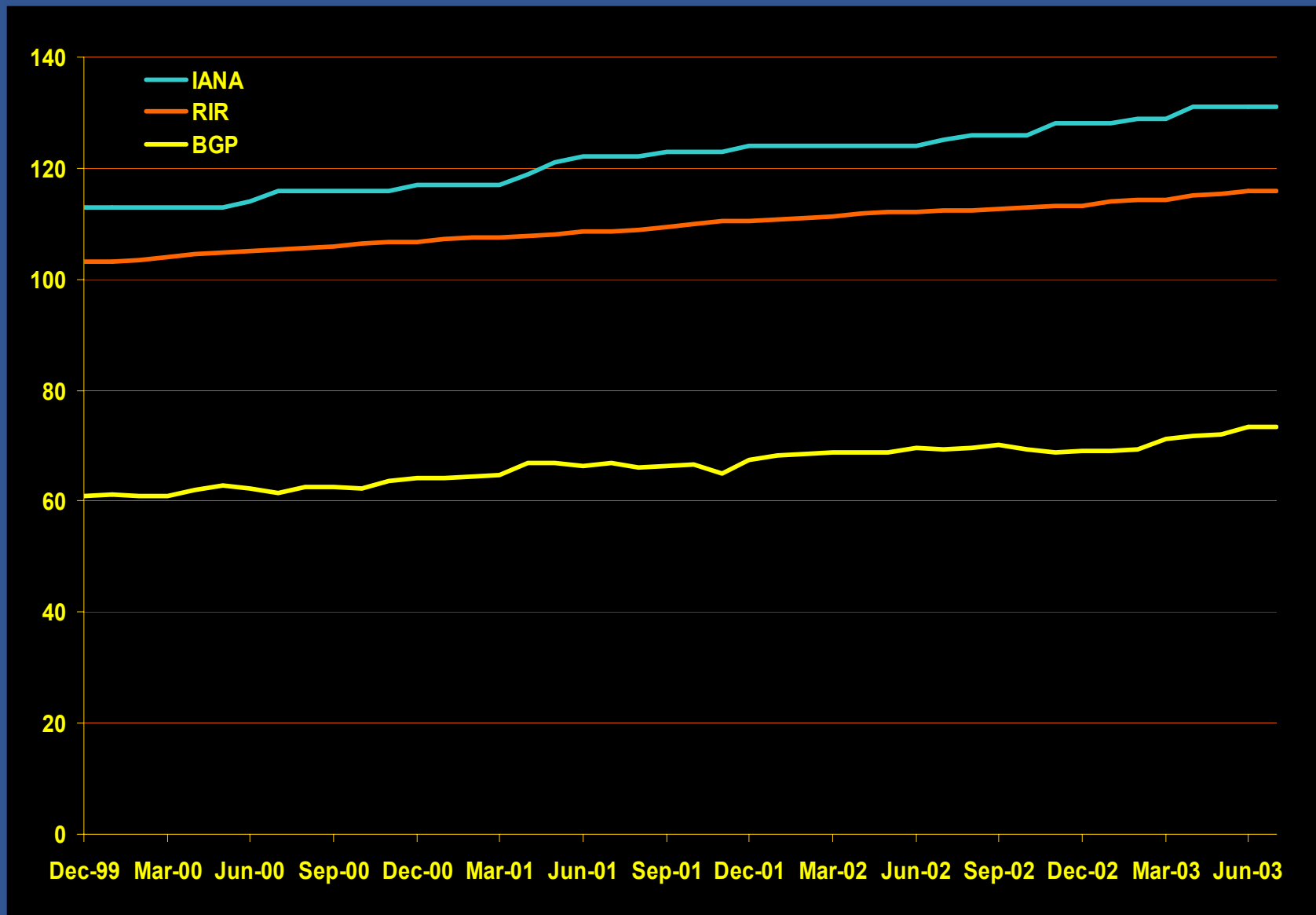


Combining the Data

Combining the Data



Recent Data (3 years)



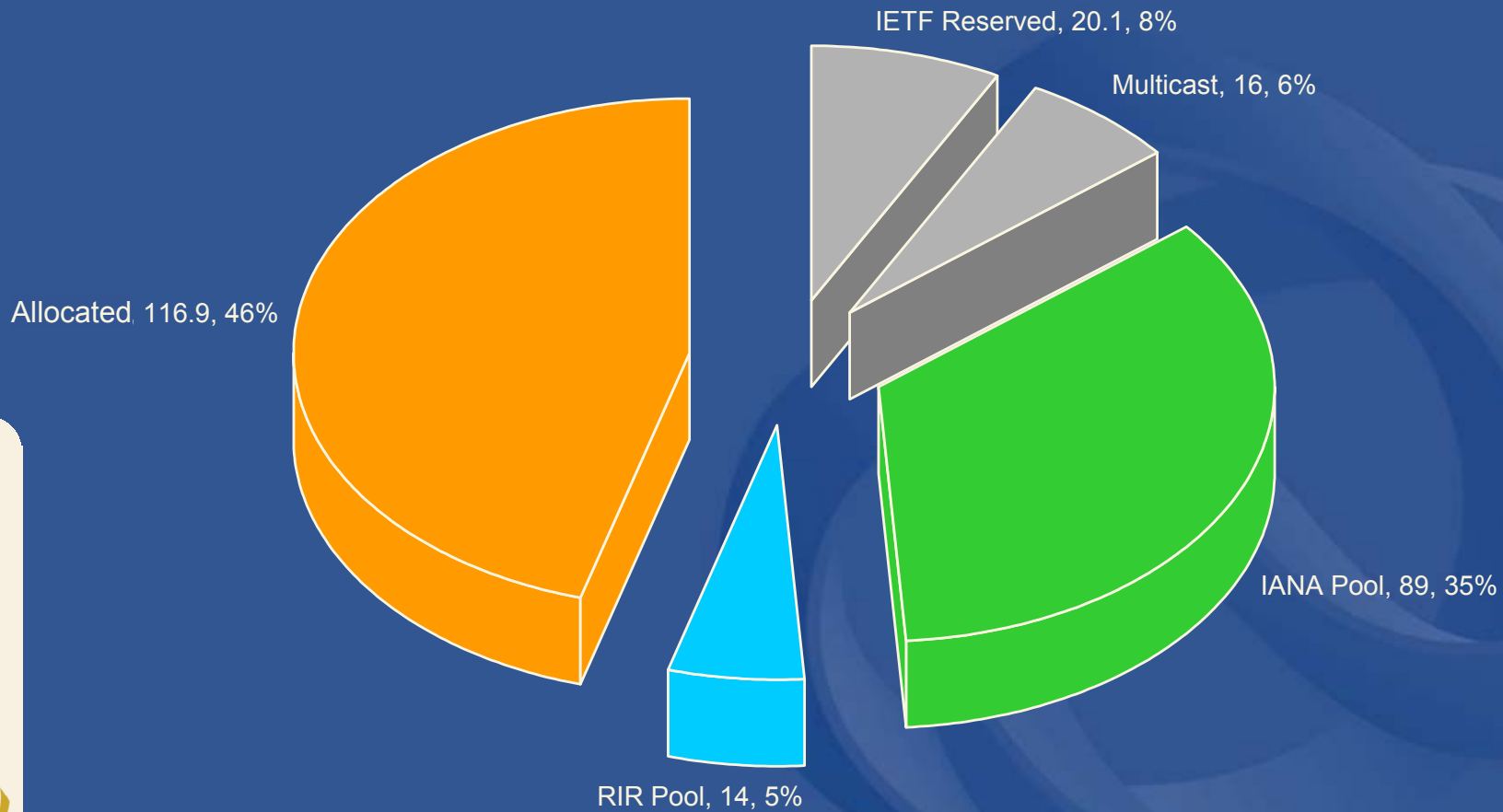
Holding Pools

A large, abstract graphic in the bottom right corner of the slide. It consists of several overlapping, curved, blue bands that form a complex, swirling pattern, resembling a stylized knot or a series of interlocking loops.

Holding Pools

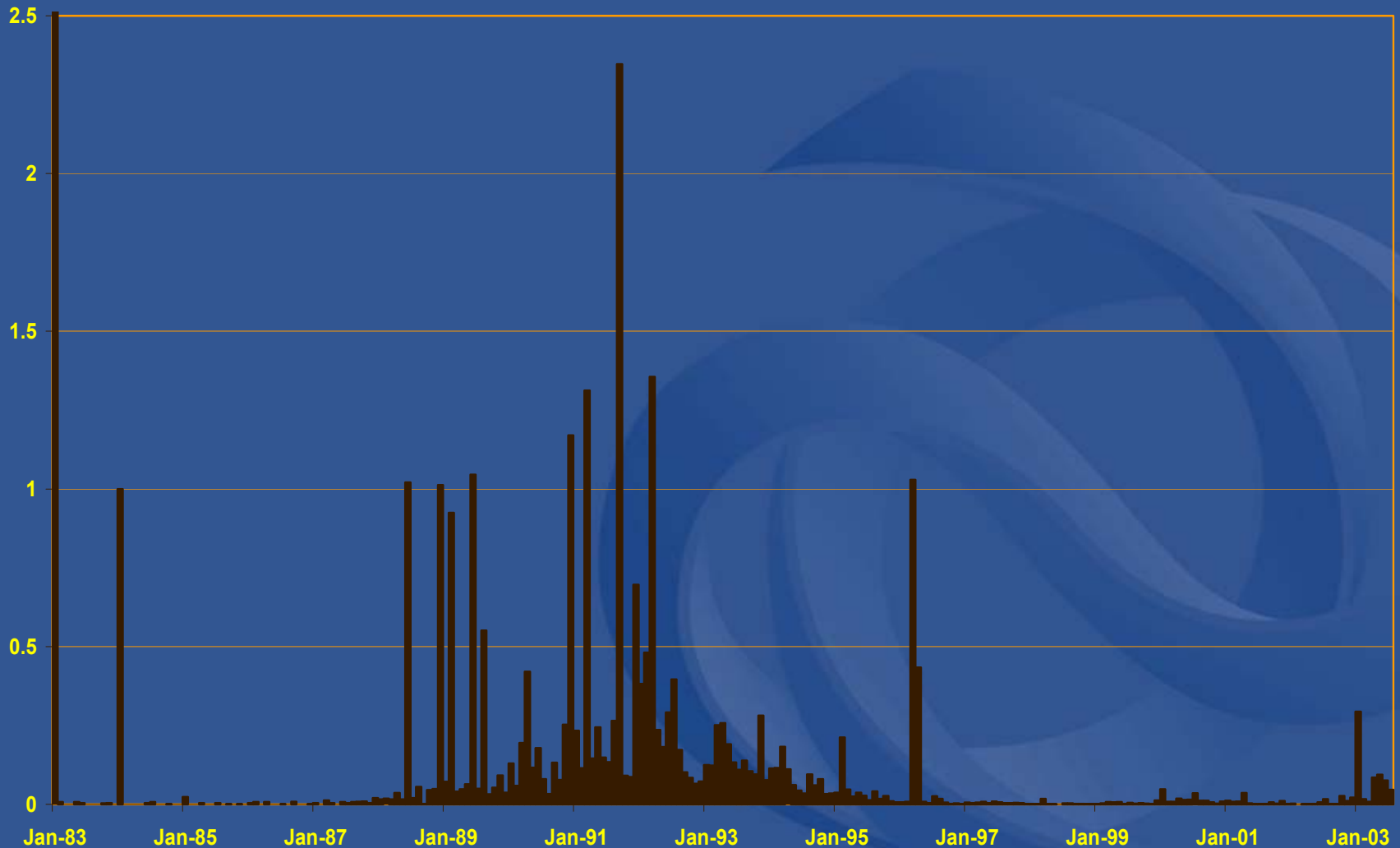
- Within IPv4 management system, some allocated address space is not used
 - Historically, substantial IANA-allocated space is still unannounced (not routed)
 - Under RIR system, RIRs hold pools of addresses for further allocation
 - Address space allocated by RIRs takes some time (small) to be announced
- These holding pools can be incorporated into the address space consumption model

Total Allocations - Current



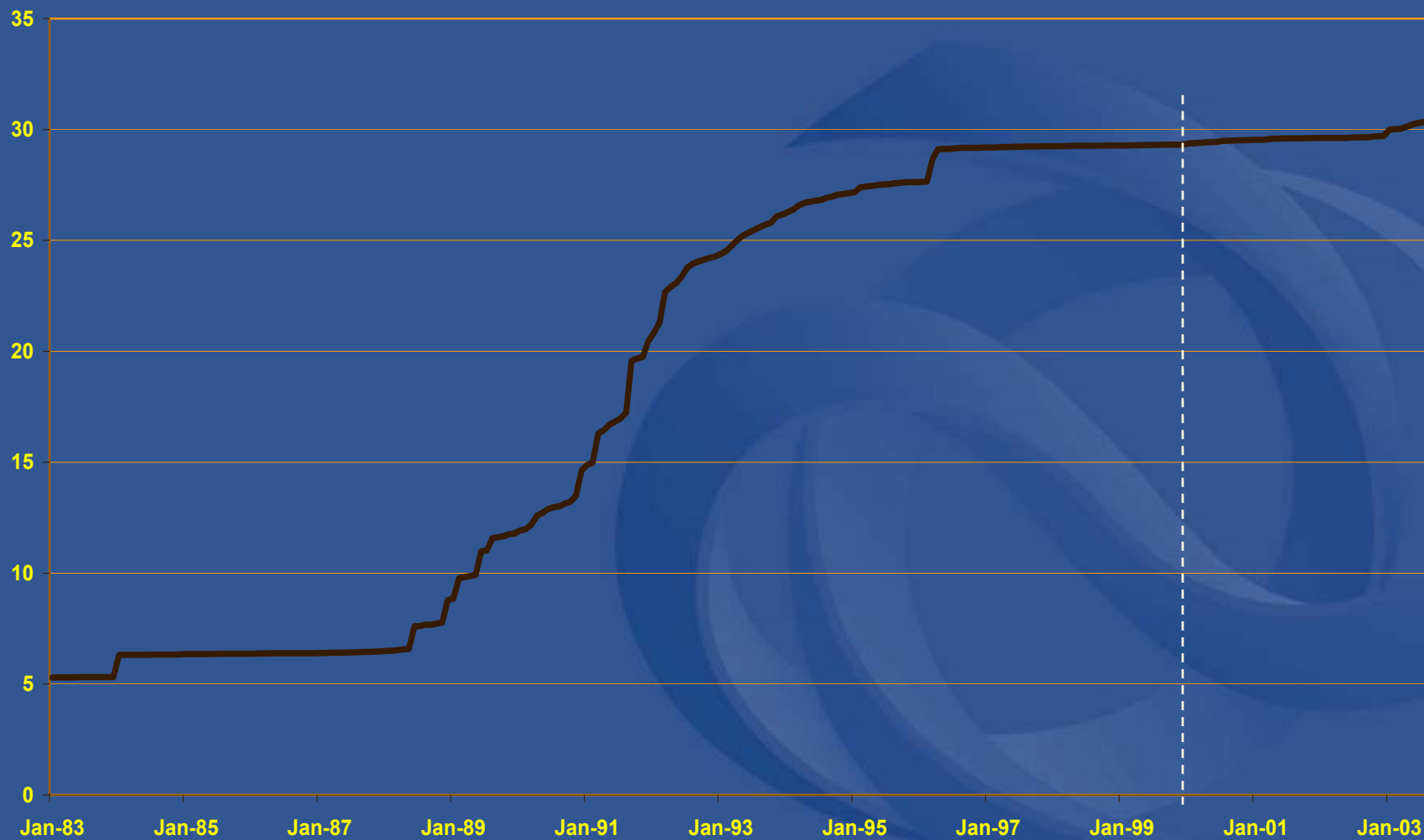
Unannounced pool - History

Age Distribution of Unannounced Address Space (/8s)



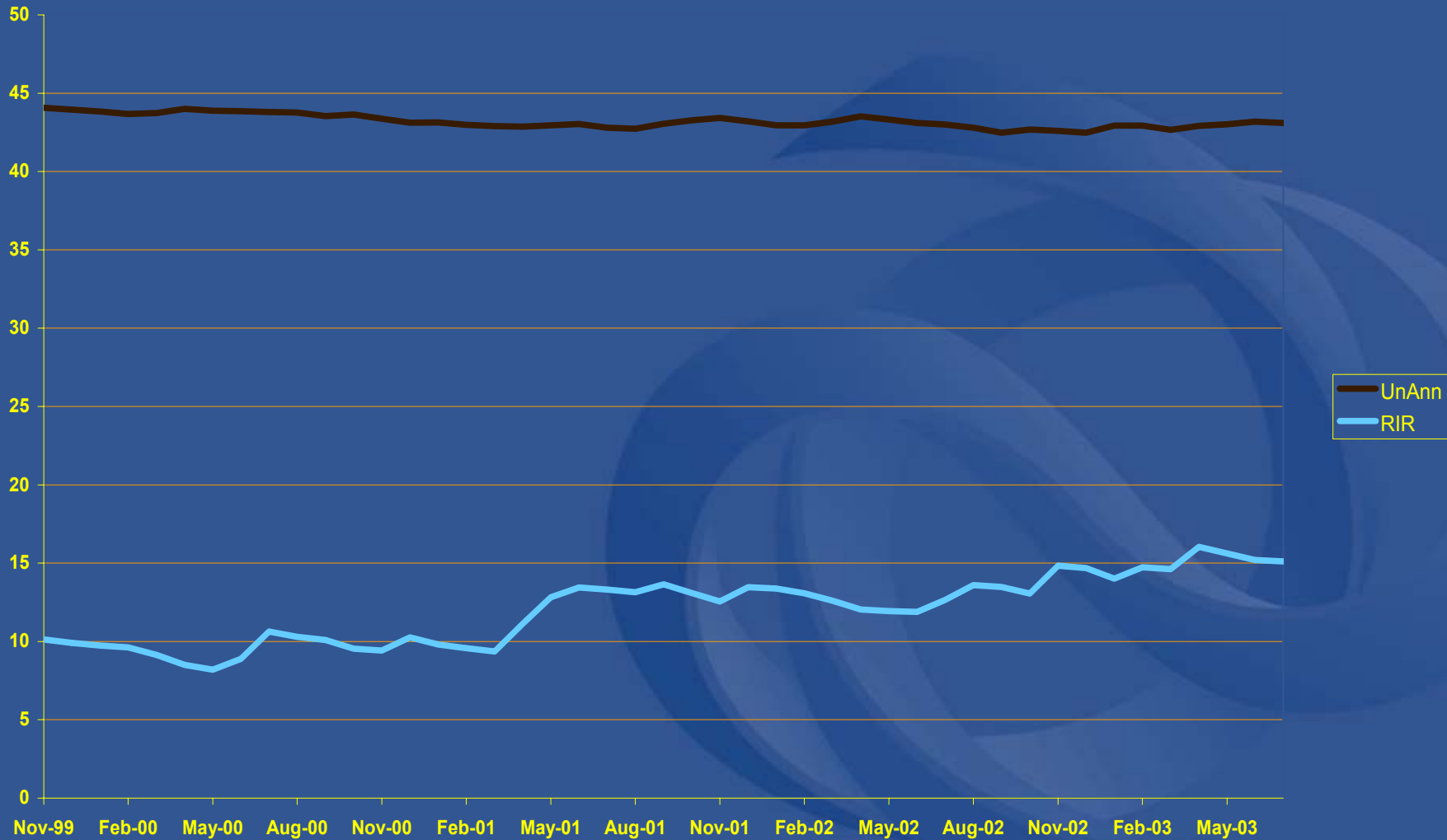
Unannounced pool - History

Cumulative total Unannounced Address Space (/8)



Holding Pools: RIR & Unannounced

Size of Holding Areas (/8)



Holding Pools: projection

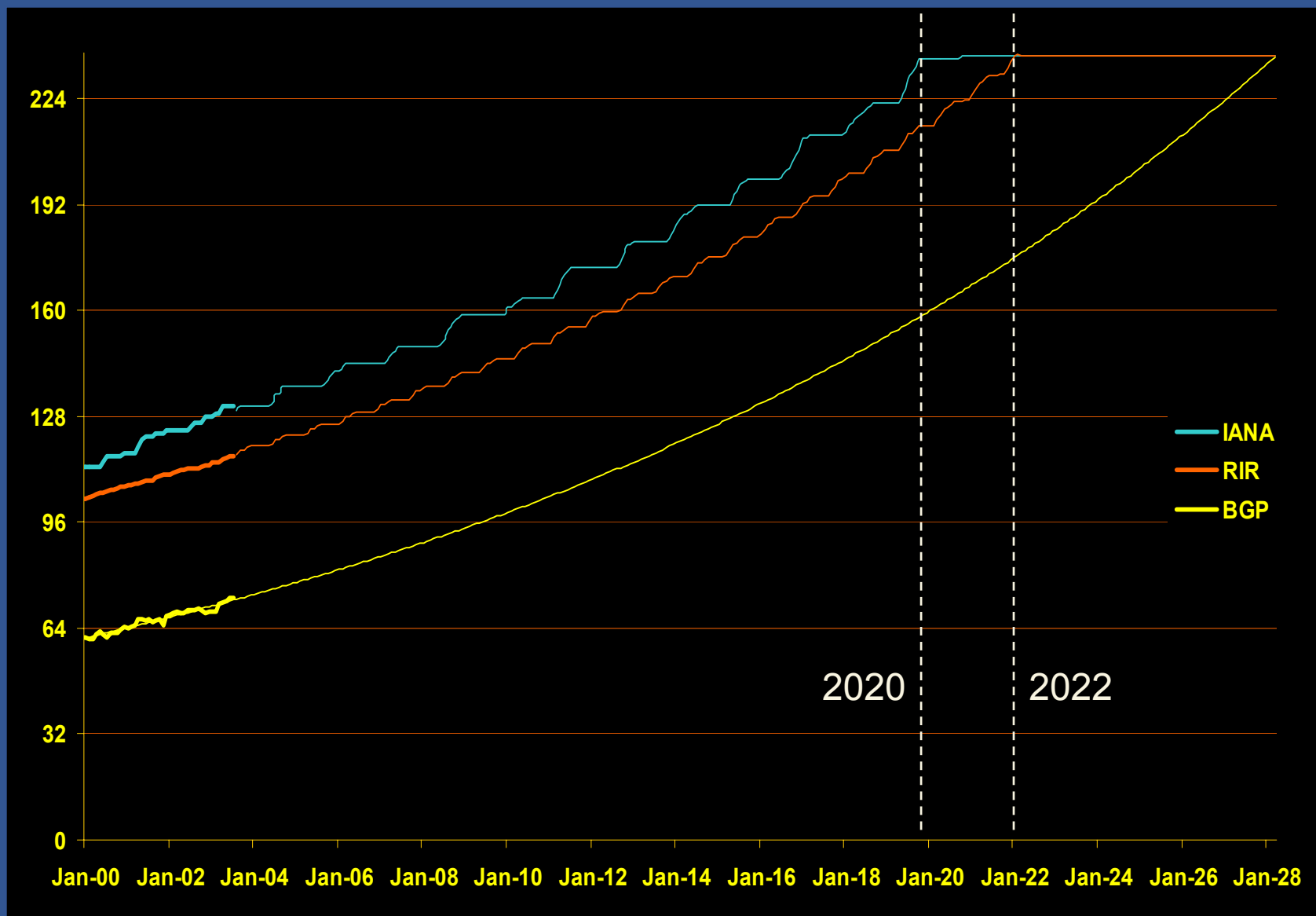
- Assume that the RIR efficiency in allocation slowly declines, with address holdings
 - RIR holding pool will slowly increase over time
- Assume that the Unannounced space behaves predictably
 - Shrinks at the same rate as over past 3 years

Modeling the Process

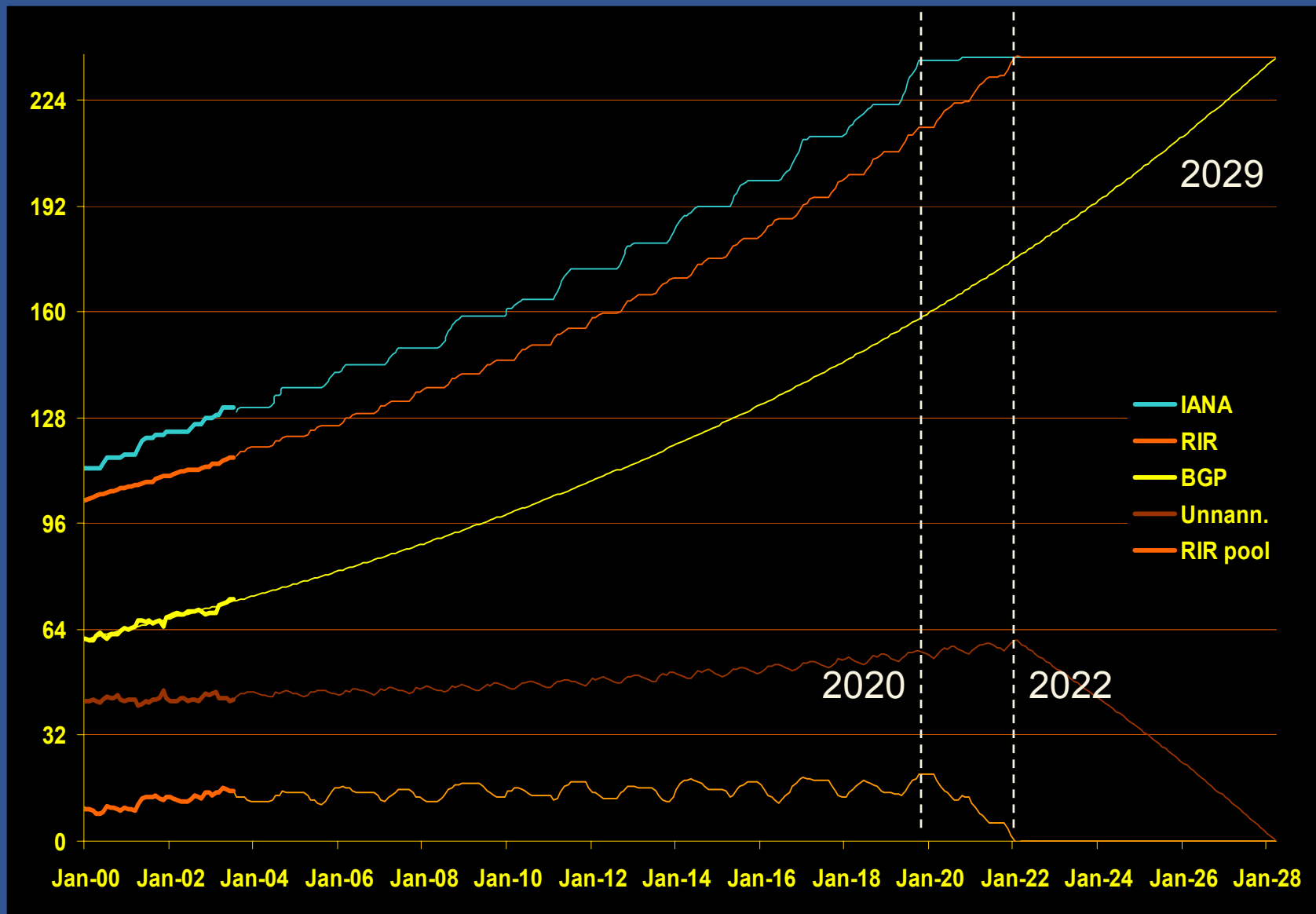
Modeling the Process

- Put together all the data
 - IANA projections
 - RIR projections
 - BGP projections
 - Holding pool analysis
- Assume exponential best fit model for address space projections
- Also look at linear projections as indicated by the routing table analysis

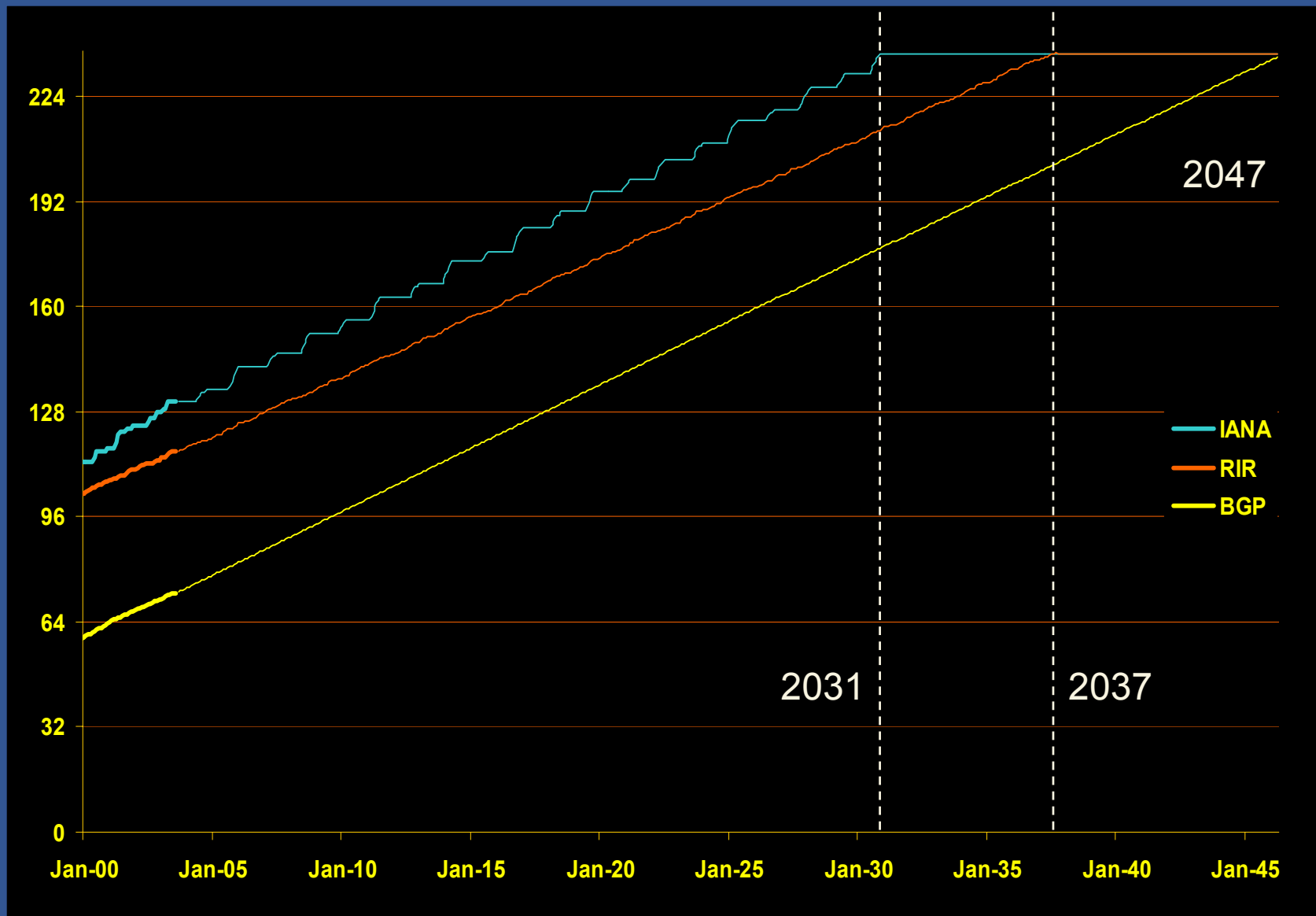
Process model - exponential



Process model - exponential



Process model - linear



Methodology and Caveats

- Projection of based on 2000-2003 data
 - IANA and RIR allocation practices
 - BGP-based demand model
- Incorporating
 - RIR unallocated pool
 - Total address space including allocated but unannounced
- Exponential growth model
 - Address space lasts until 2022
 - or 2029 if all unannounced space recovered
- Linear growth model
 - Address space lasts until 2037 (or 2047)

Some Big Issues

- This is just a model - reality will be different!
- Will the BGP routing table continue to reflect allocation rates?
- Is the model of the unannounced pools and RIR holding pools appropriate?
- Externalities...
 - What are the underlying growth drivers (applications and services) and how are these best modeled?
 - What forms of disruptive events would alter this model, and to what extent?
- Should address management policies change as a result of these results?

Thank you

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