IPv4 Address Lifetime

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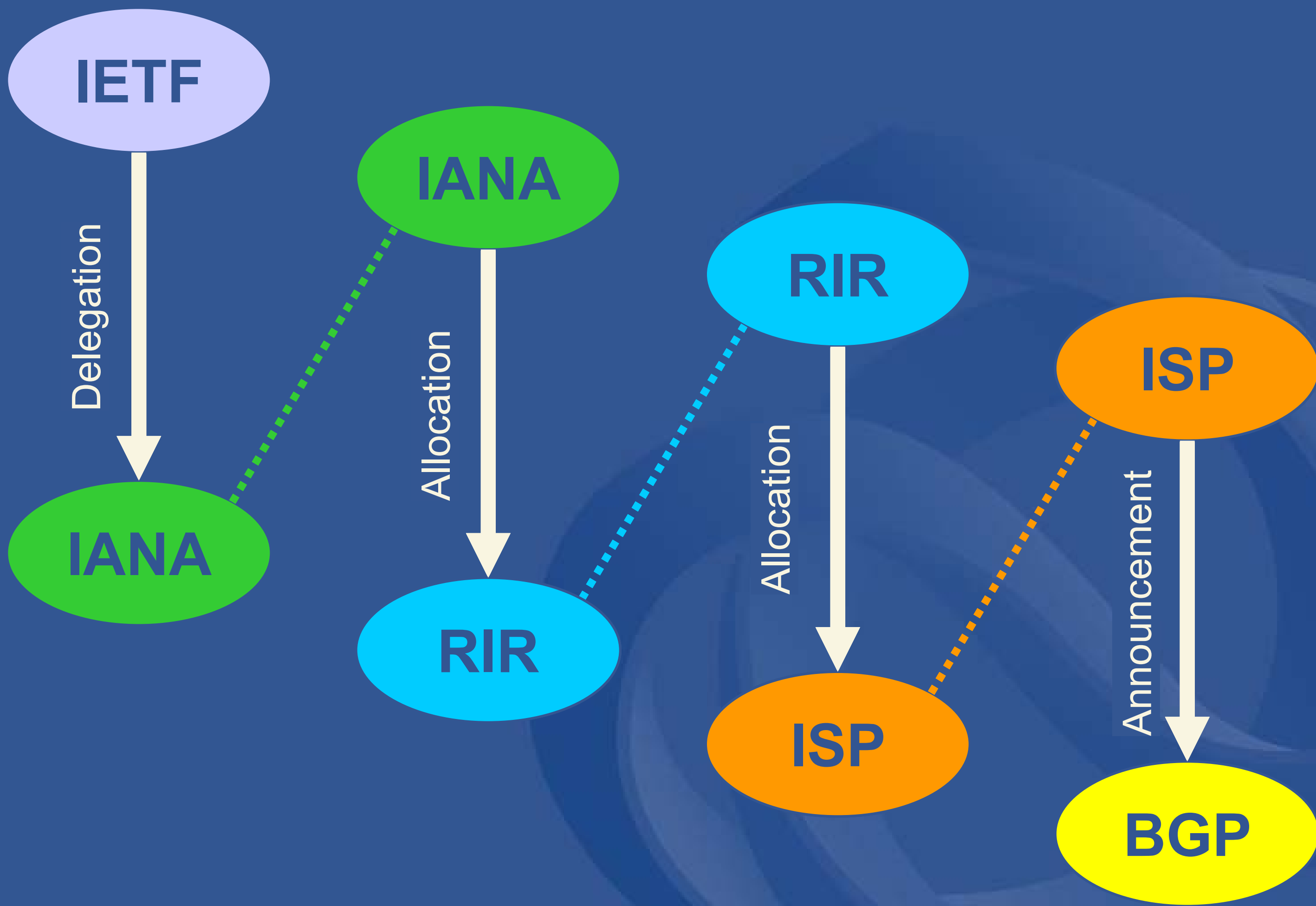
Research activity
conducted by Geoff Huston
and supported by APNIC

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

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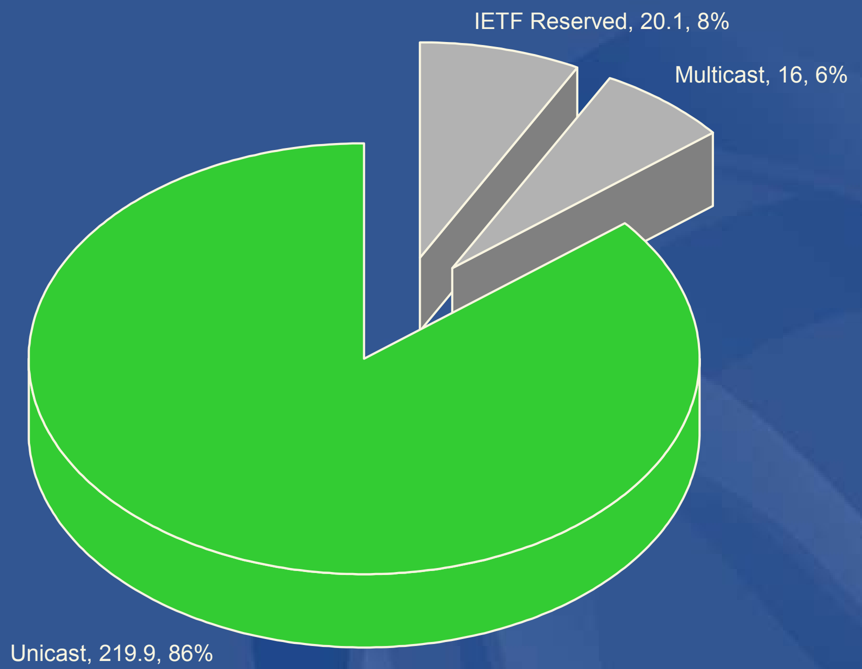
1. IETF Delegations

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



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

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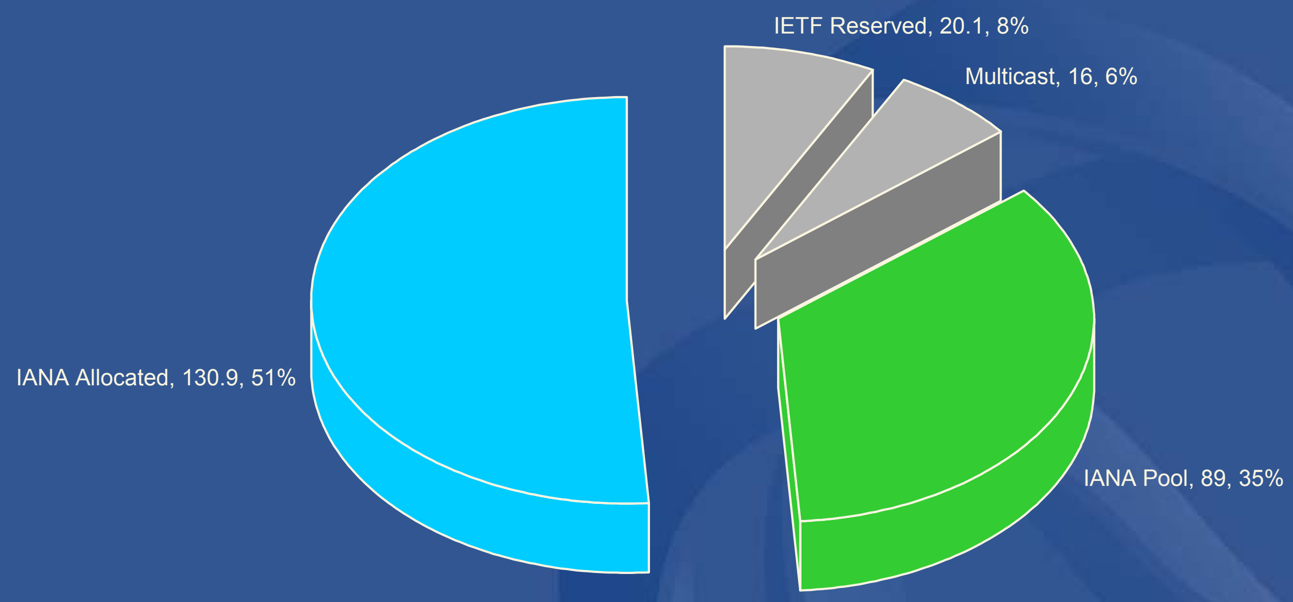
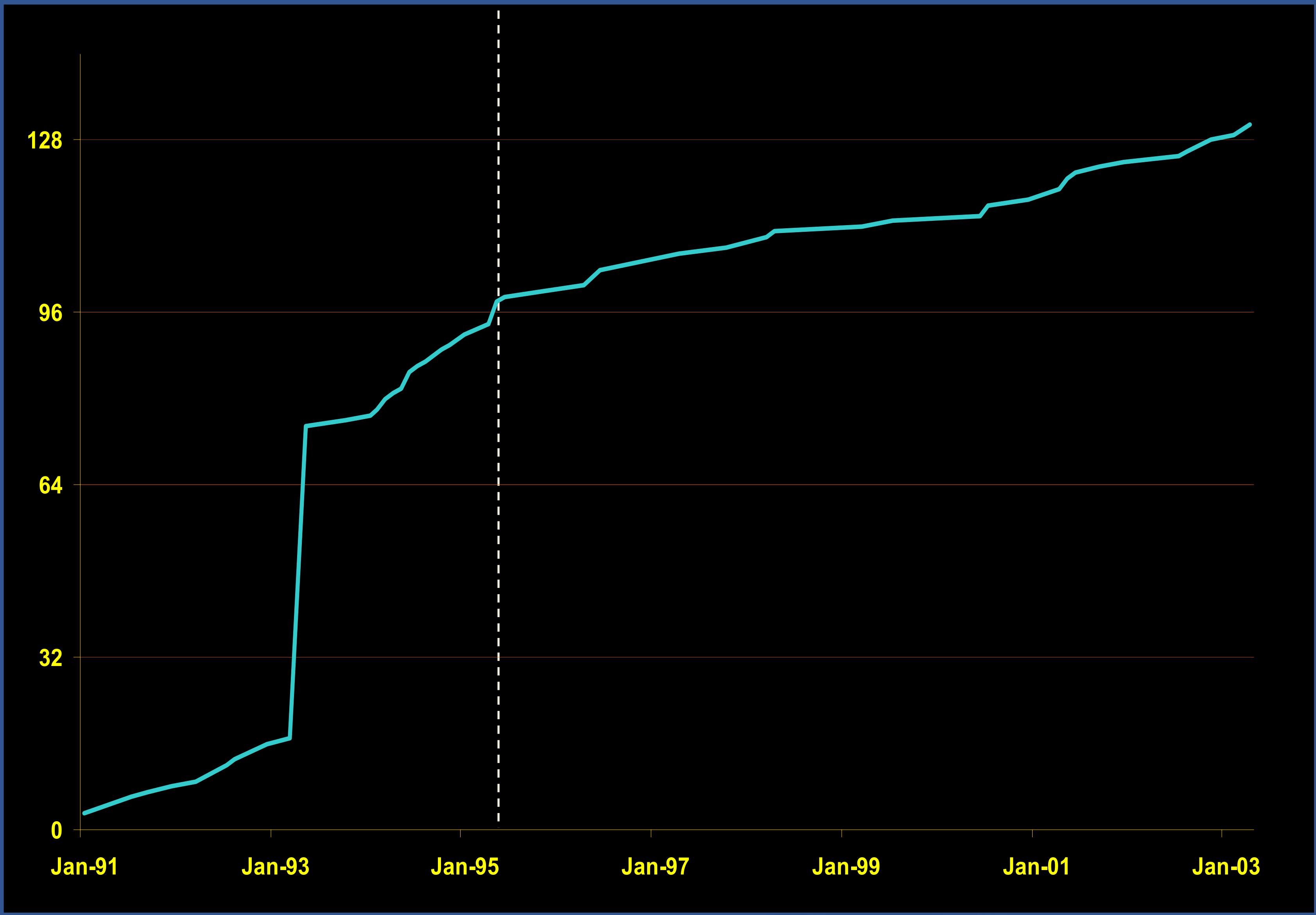
IANA Allocations - Current



IANA Allocations - Historical



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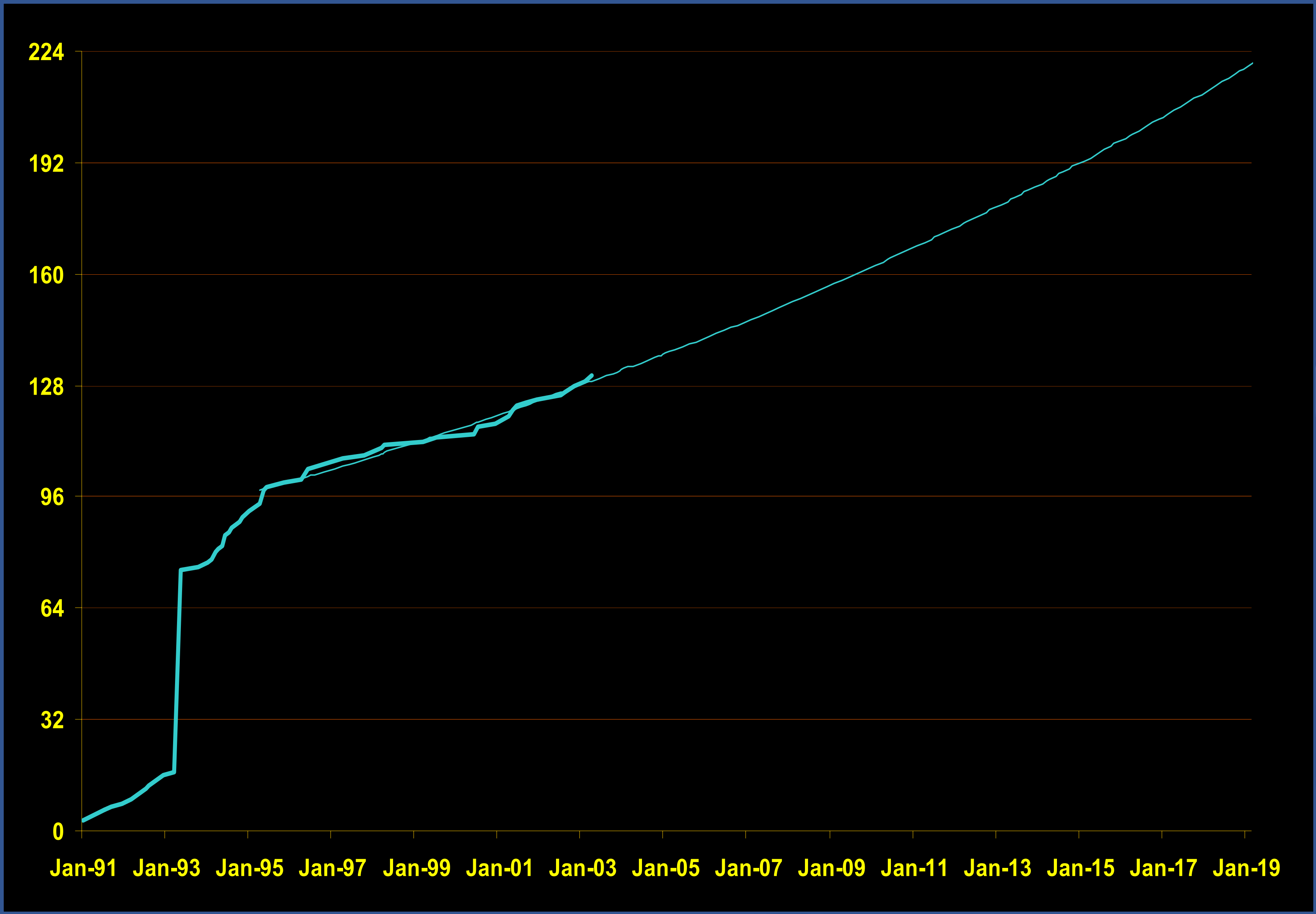
IANA Allocations - Projection



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IANA Allocations - Projection

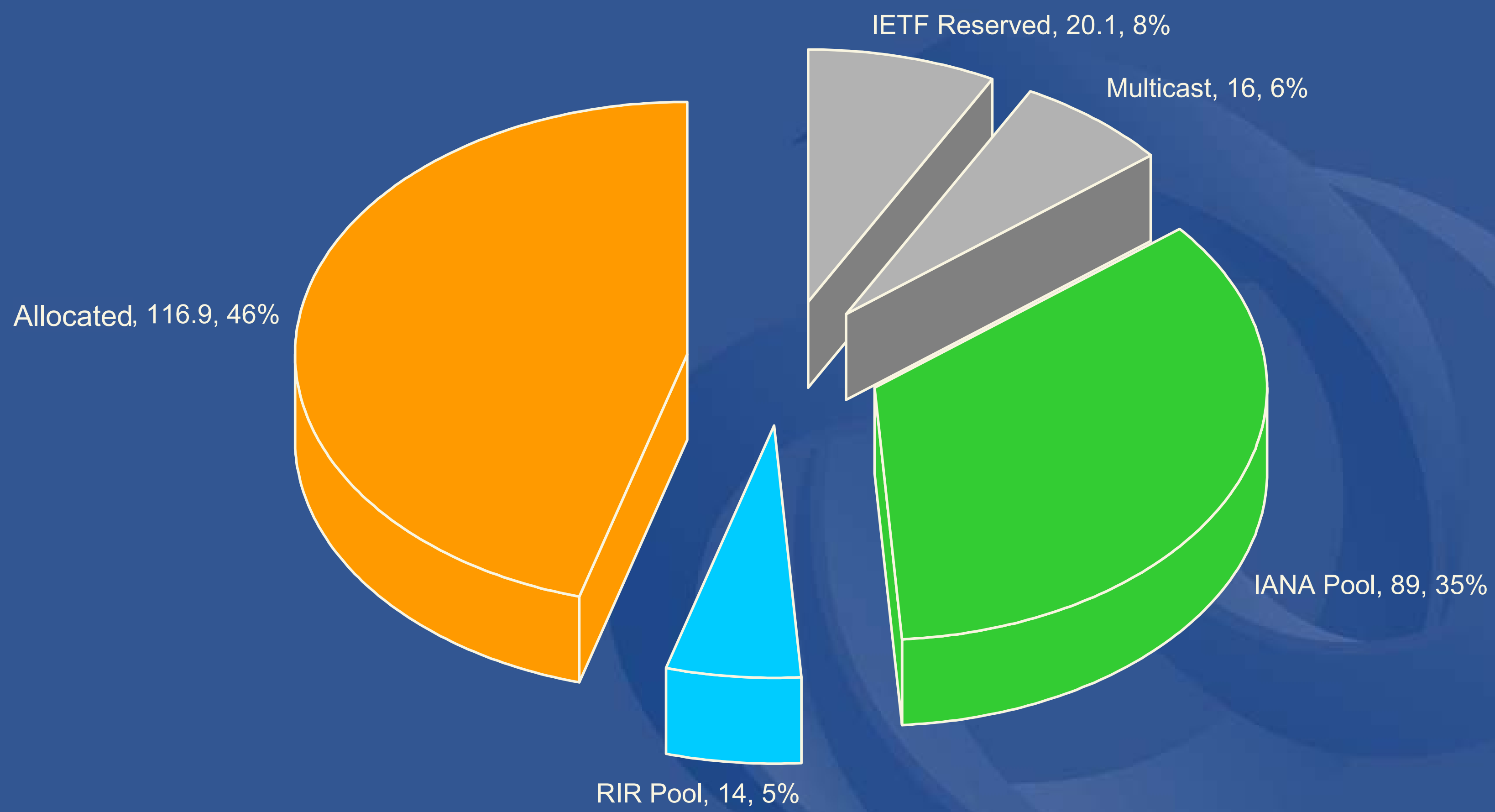
- Projected date of IANA address pool exhaustion: 2020
- This projection is very uncertain due to:
  - Sensitivity of allocation rate to prevailing RIR allocation policies
  - Sensitivity to any significant uptake up of new applications that require public addresses

3. RIR Allocations

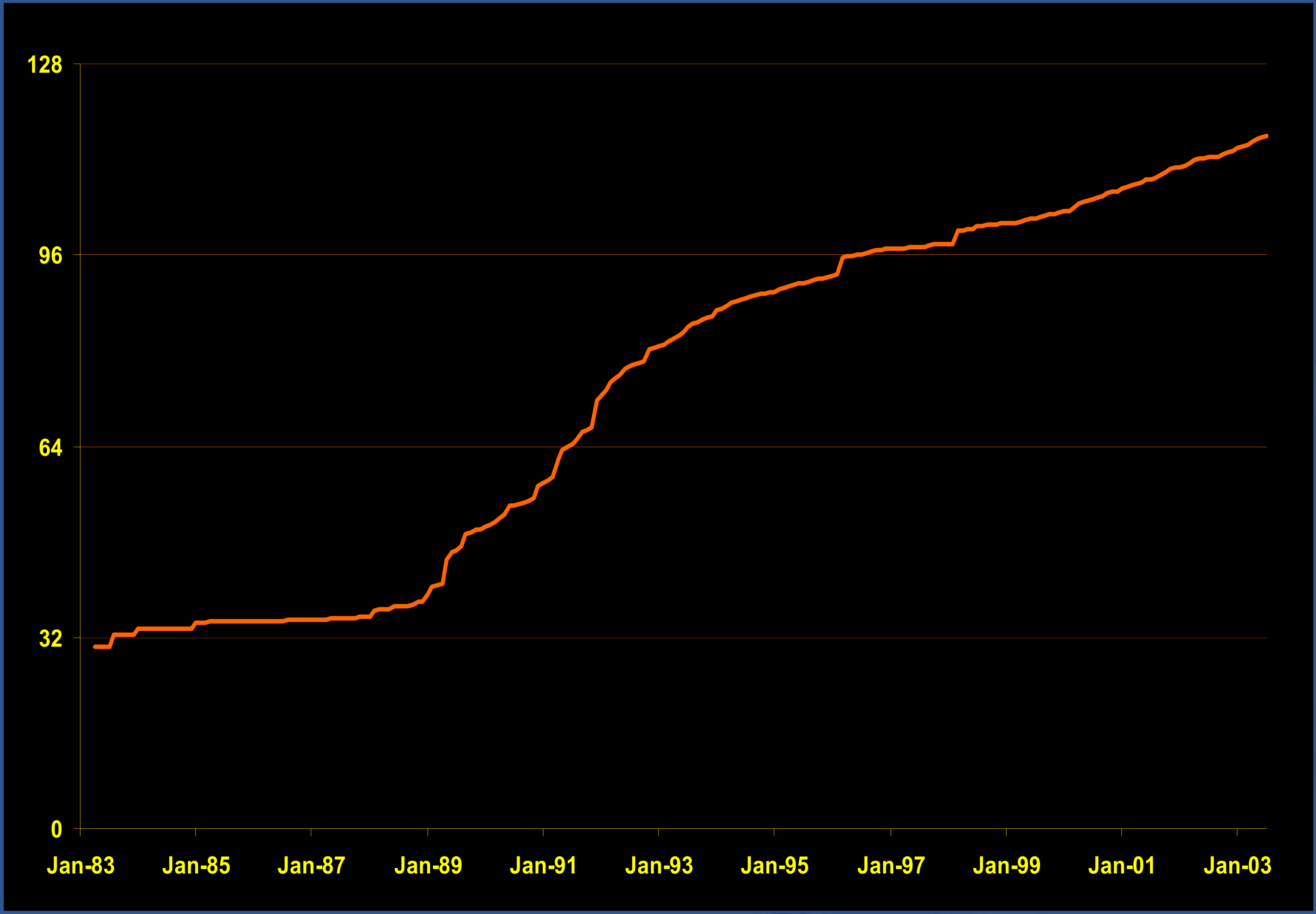
RIR Allocations

- 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

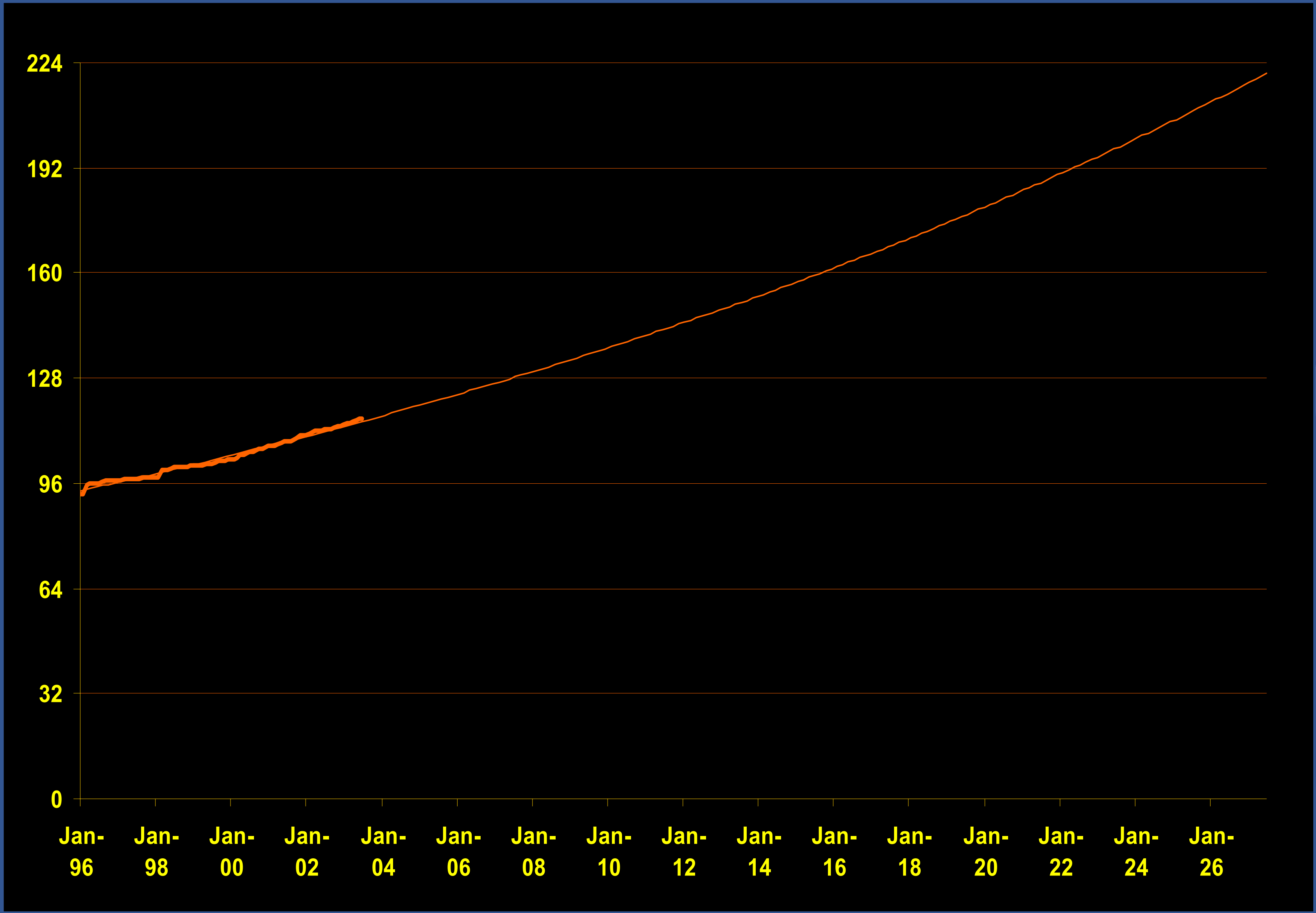
Total Allocations - Current



Total Allocations - Historical



Total Allocations - Projection



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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

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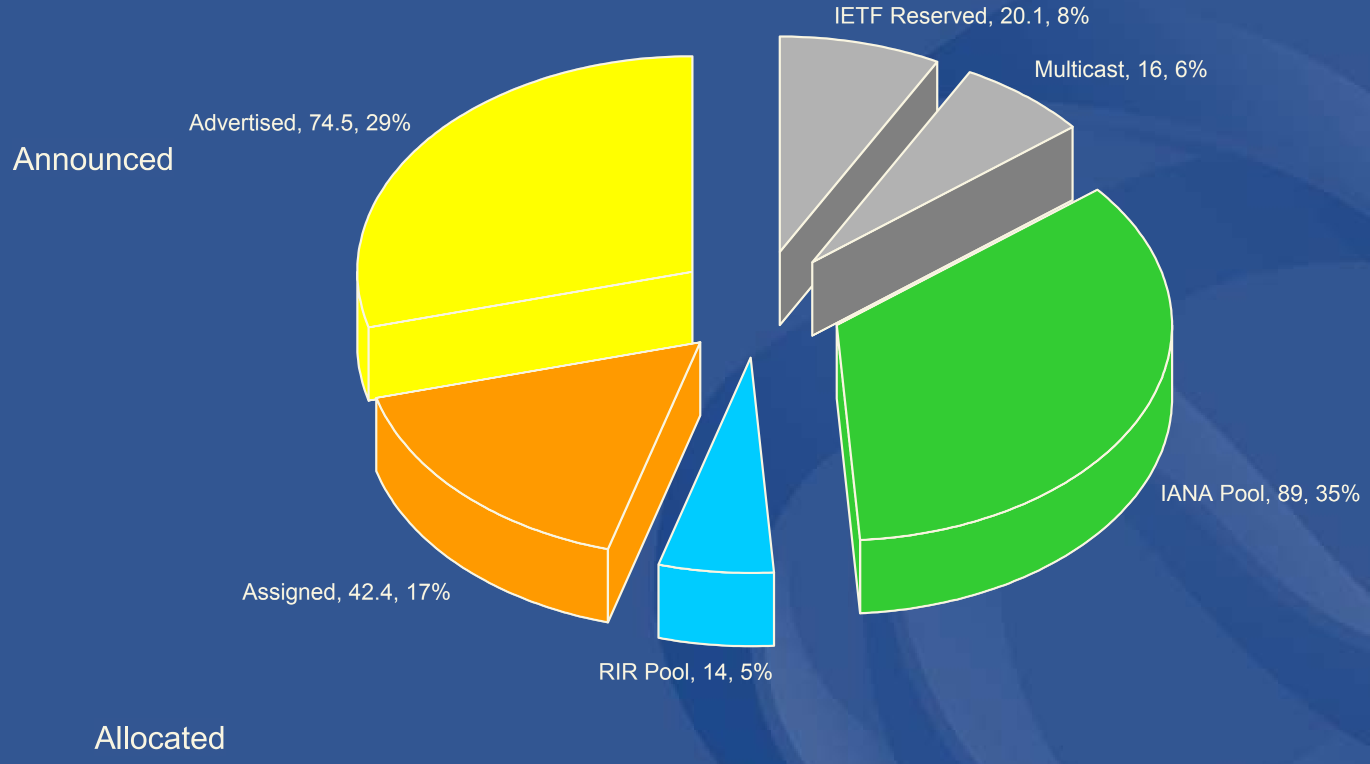
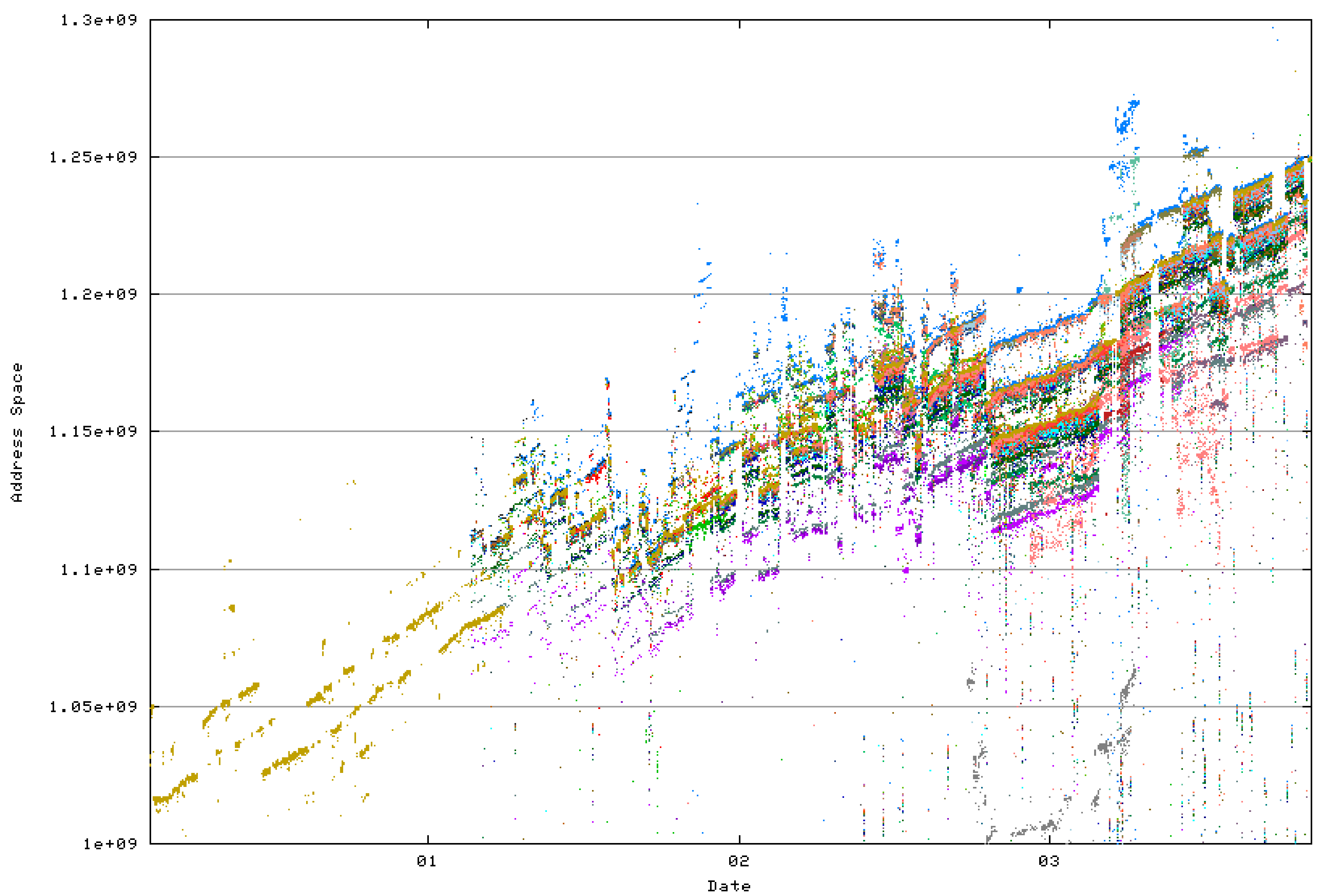
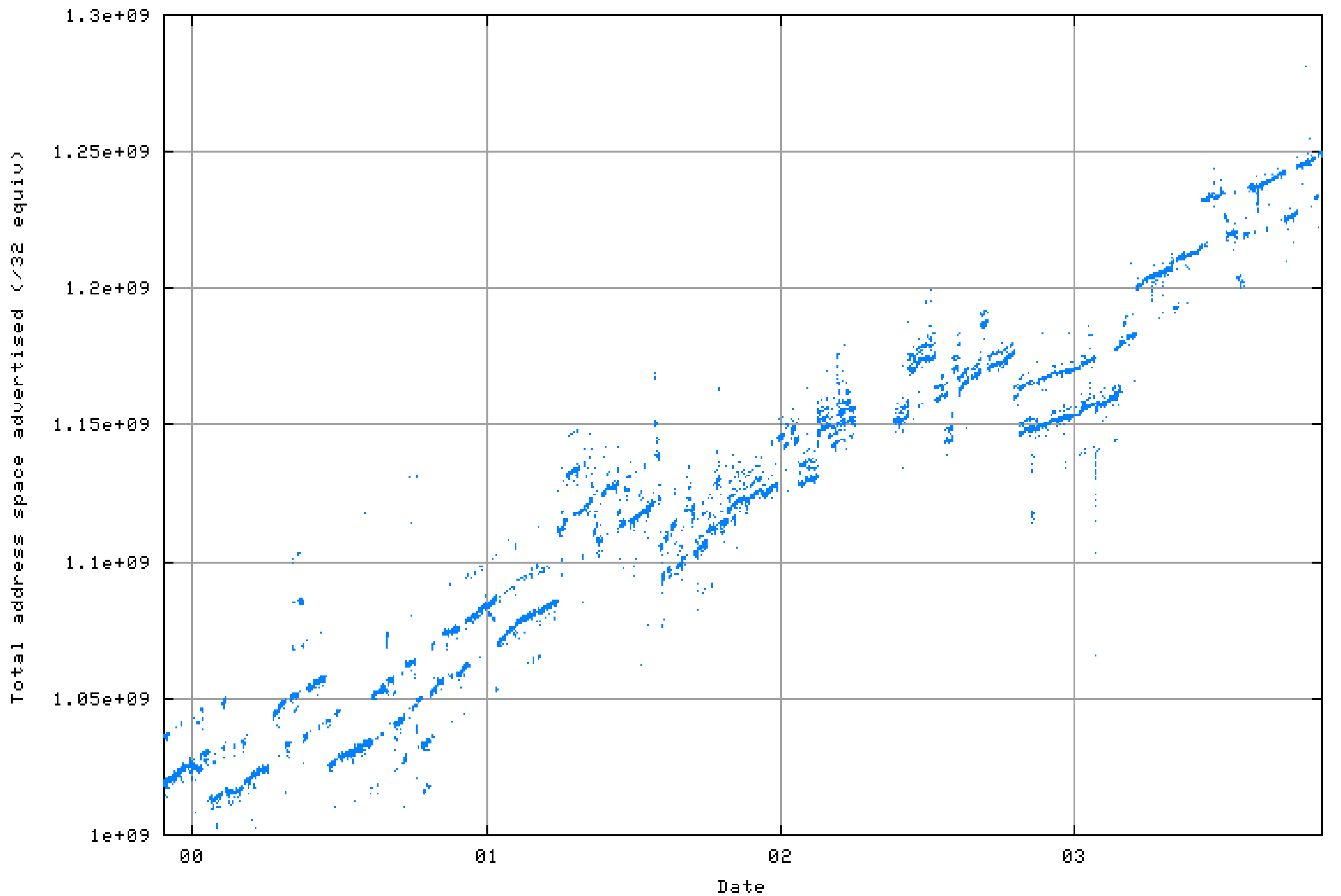
BGP Routing Table - Current



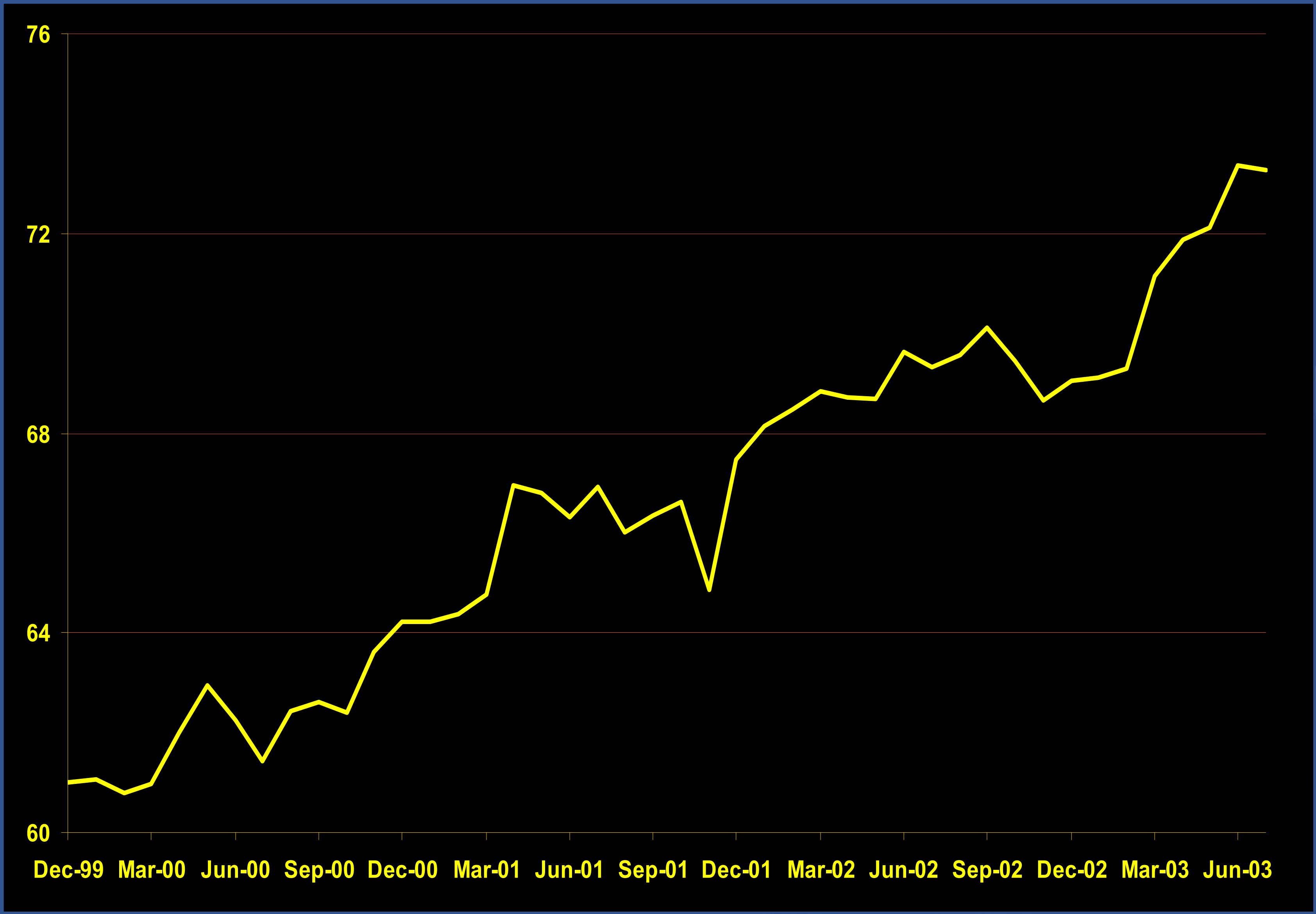
BGP Routing Table - routeviews



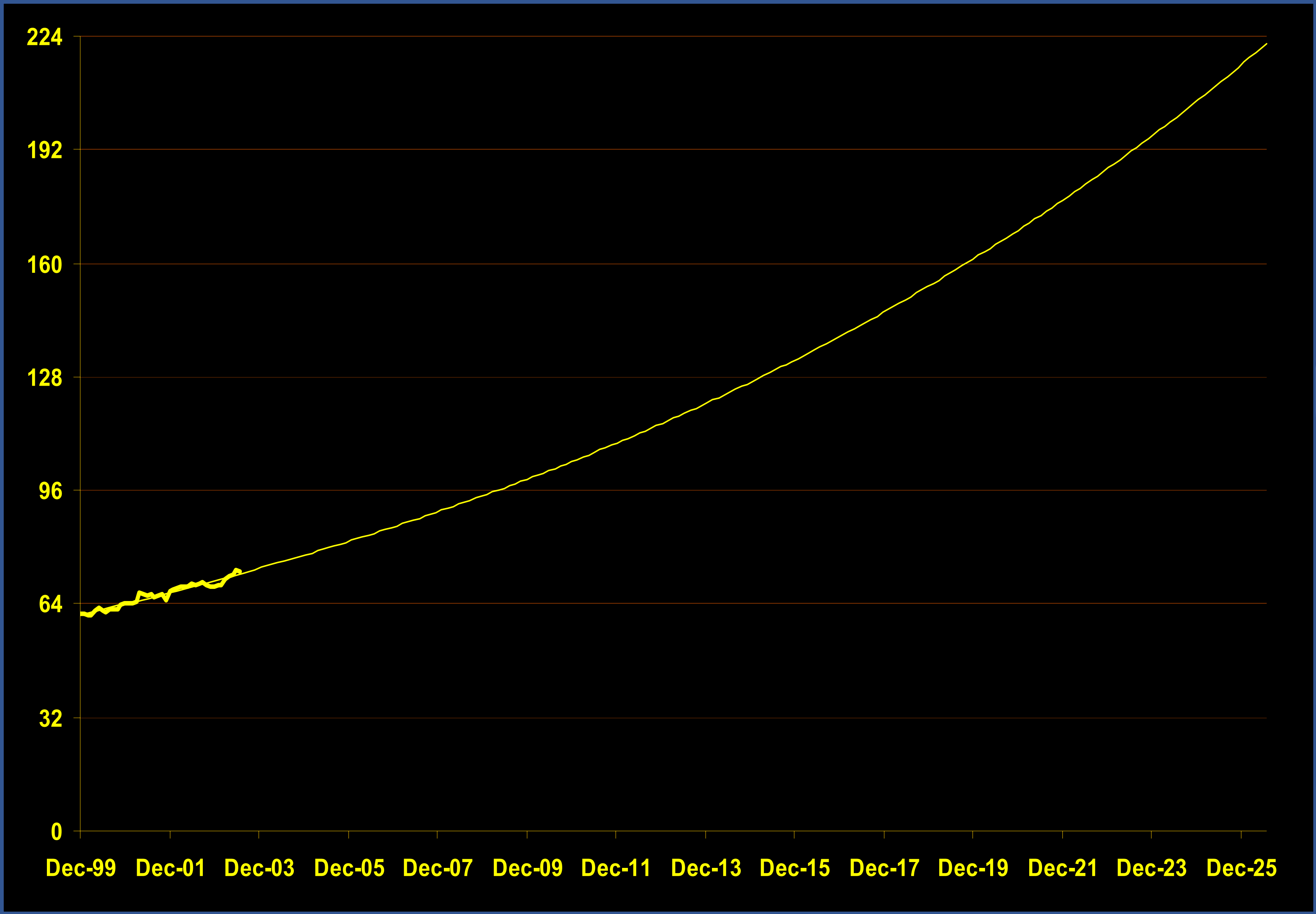
BGP Routing Table - AS1221



BGP Announcements - Historical



BGP Announcements - Projection



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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

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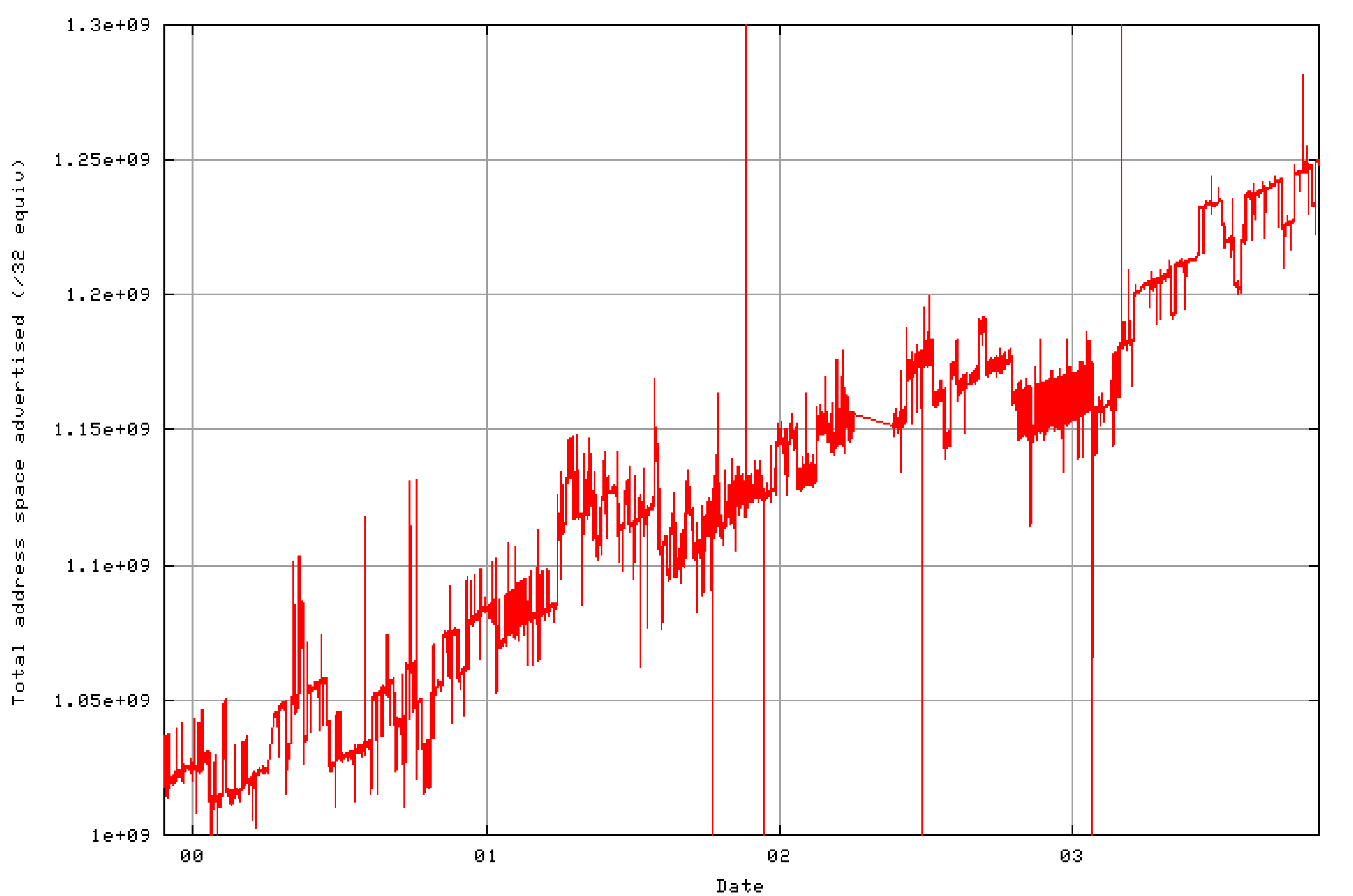
BGP Projections - Revisited

- 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…

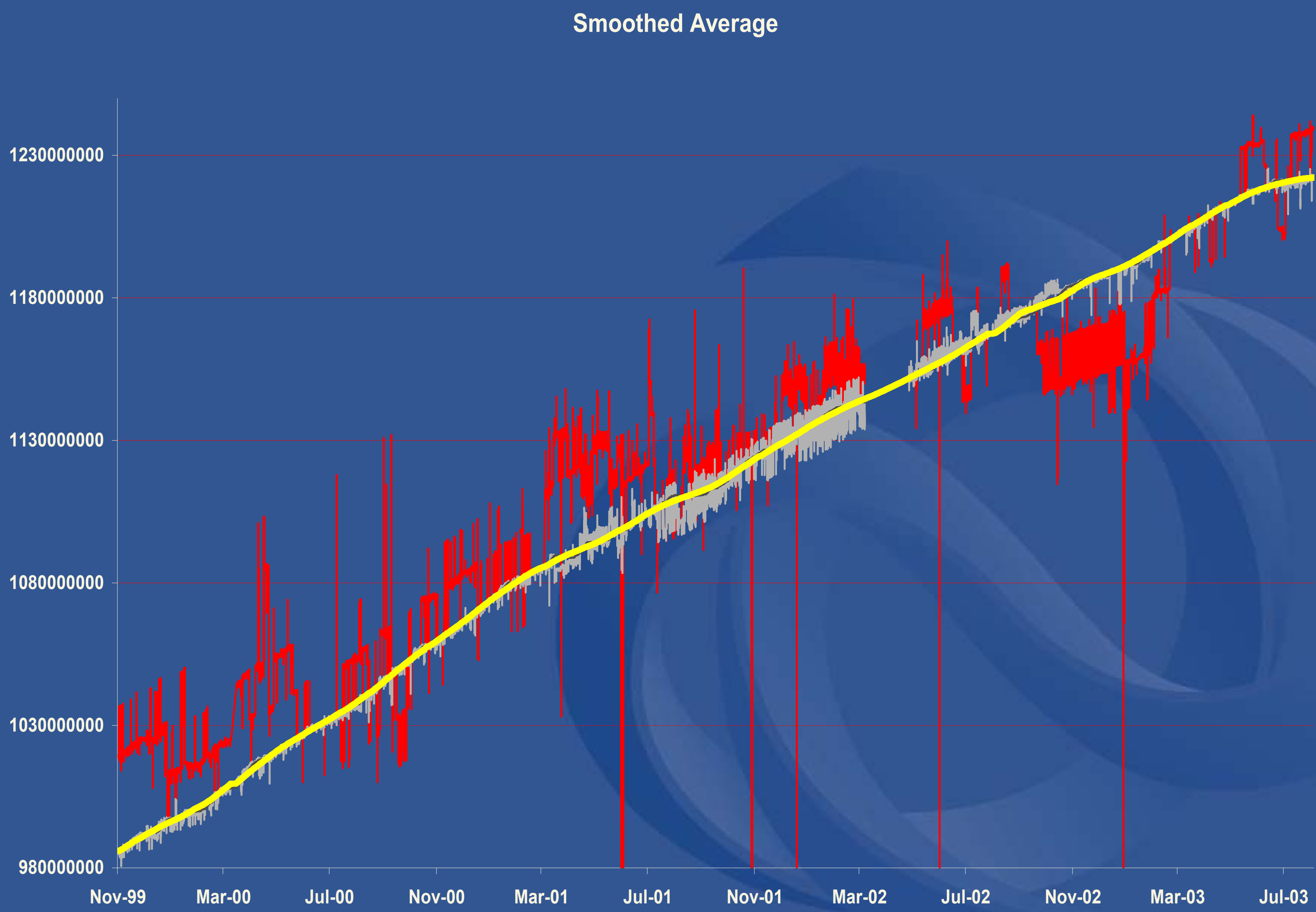
Another look at that BGP data…



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…



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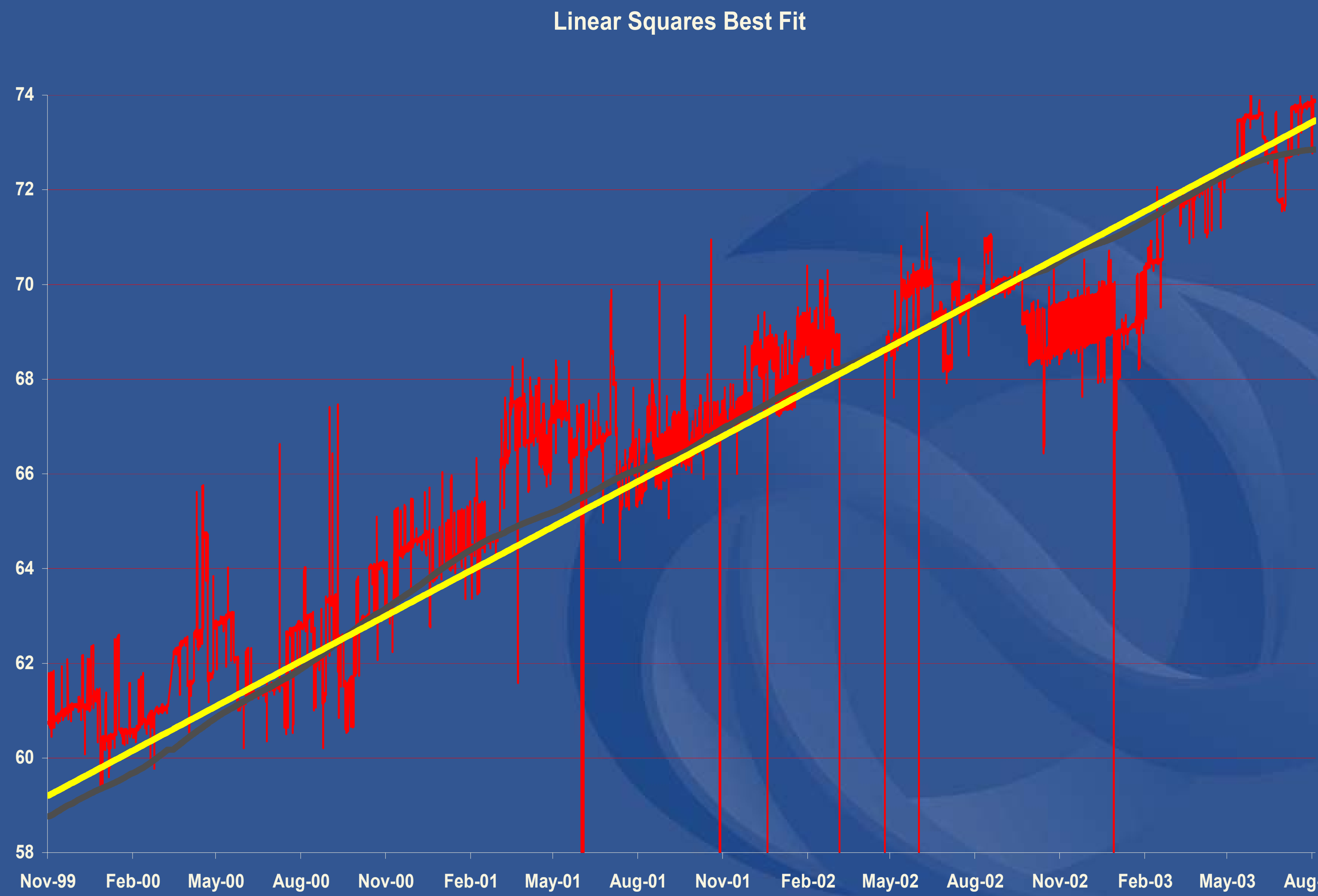
Another look at that BGP data…

- 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…



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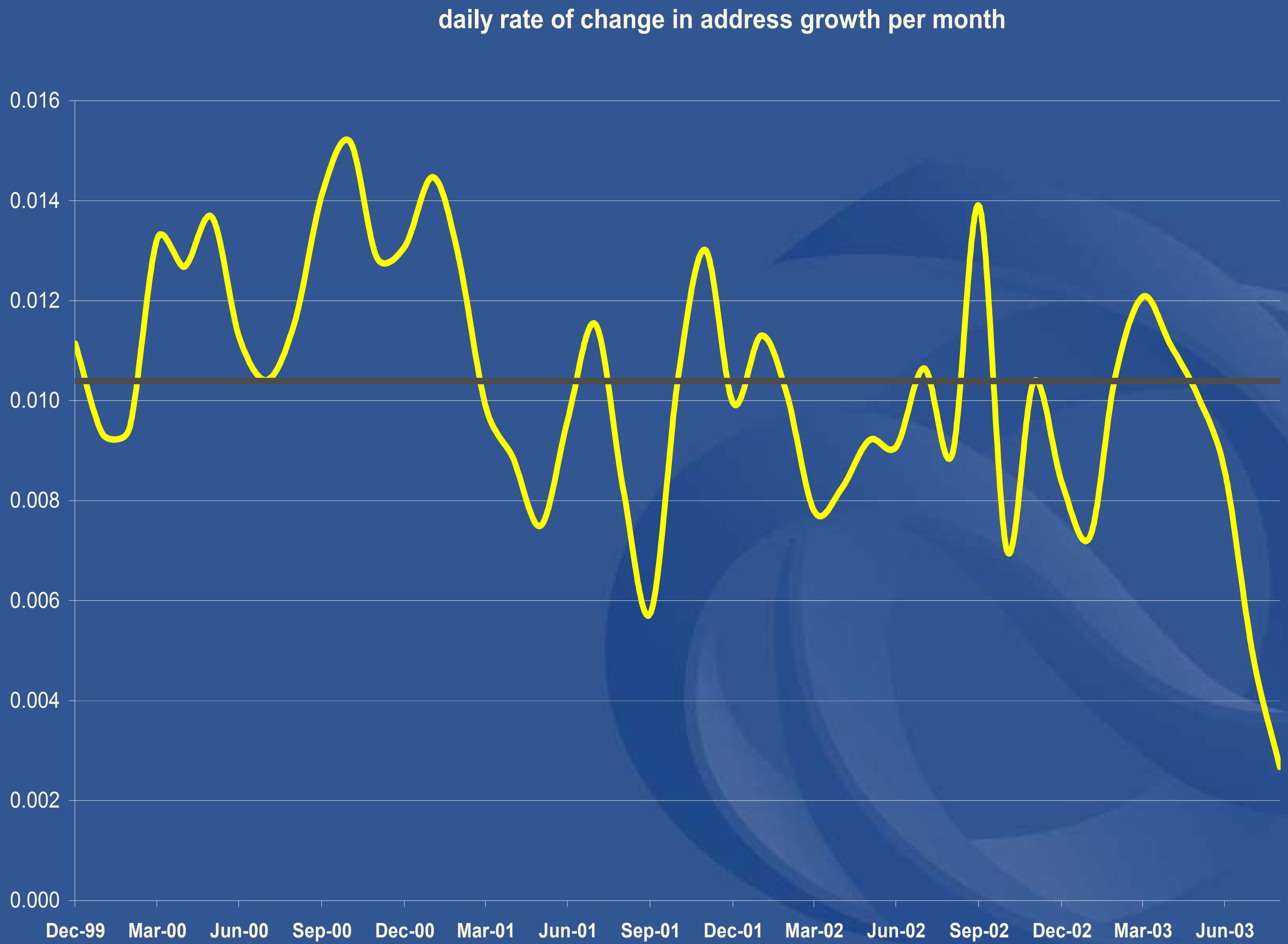
Another look at that BGP data…

- 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…



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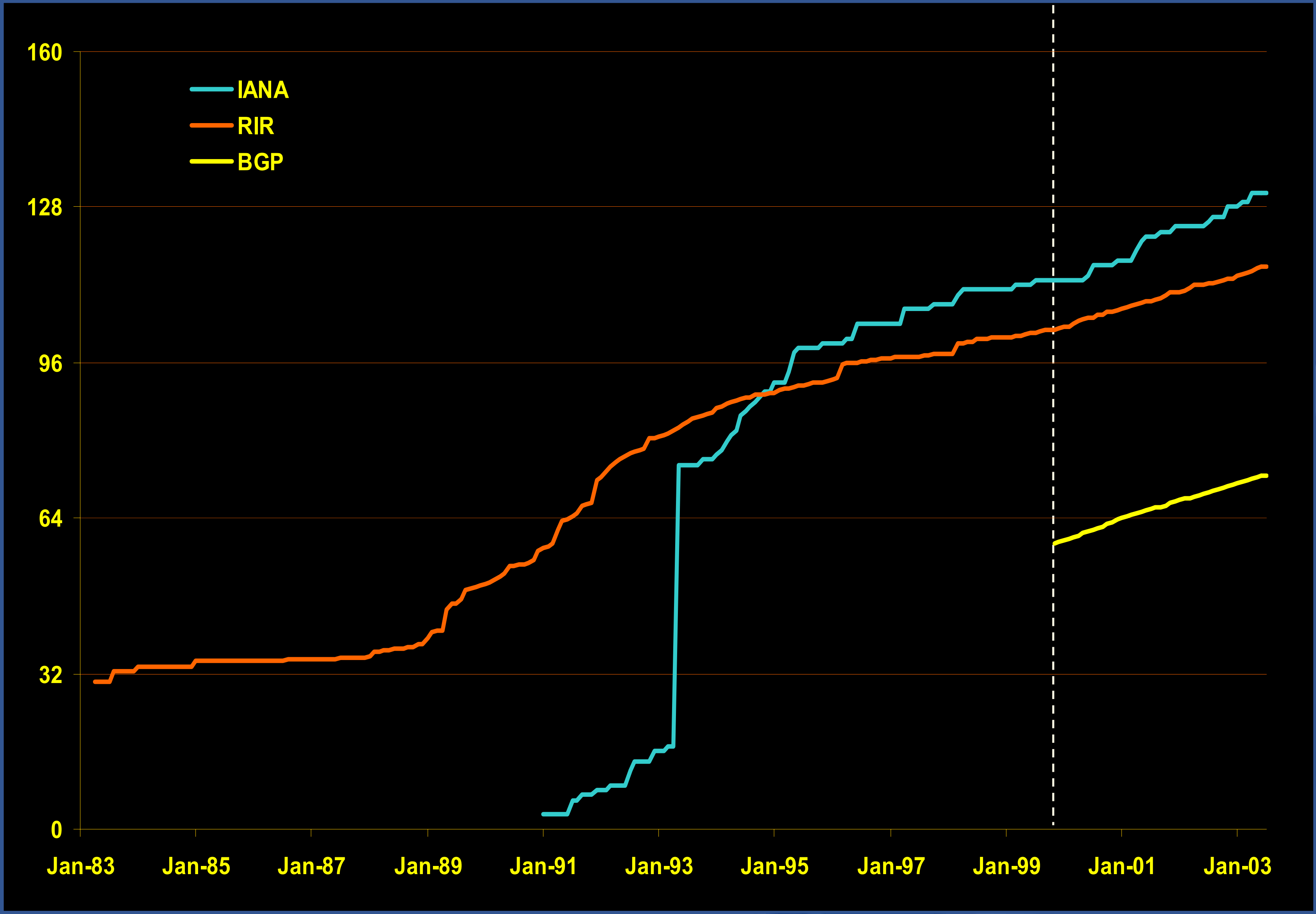
Combining the Data

Combining the Data



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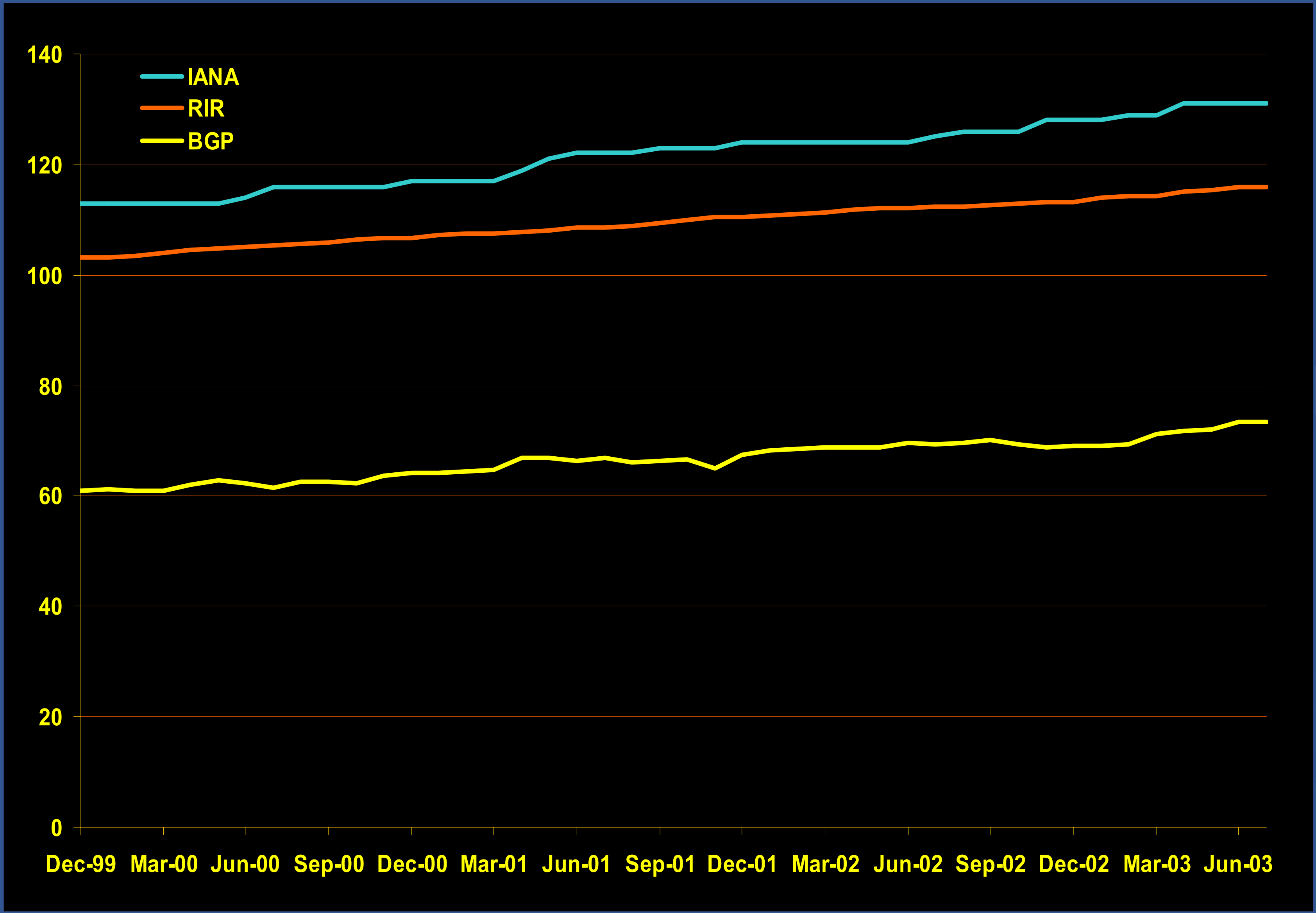
Recent Data (3 years)



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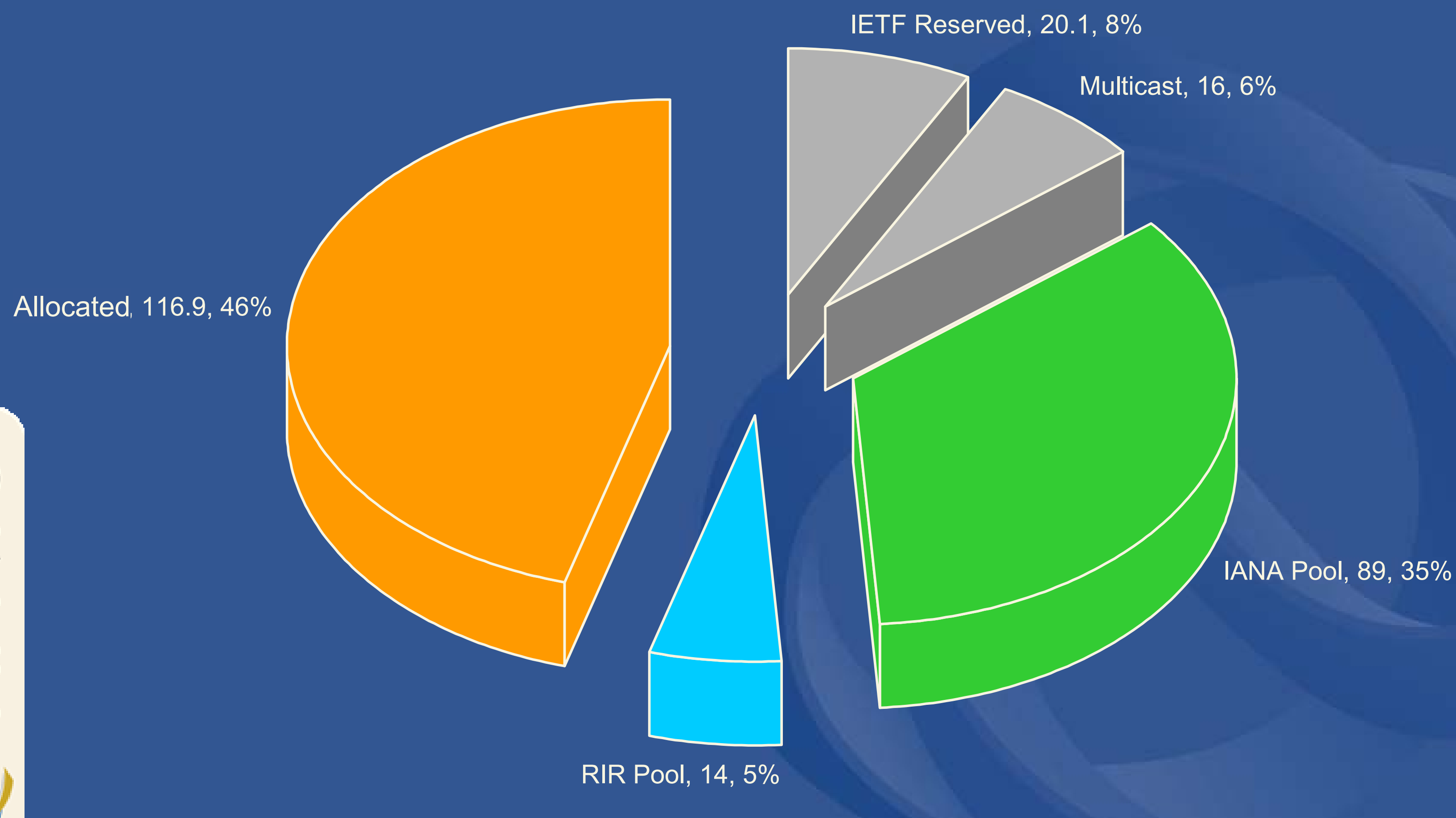
Holding Pools

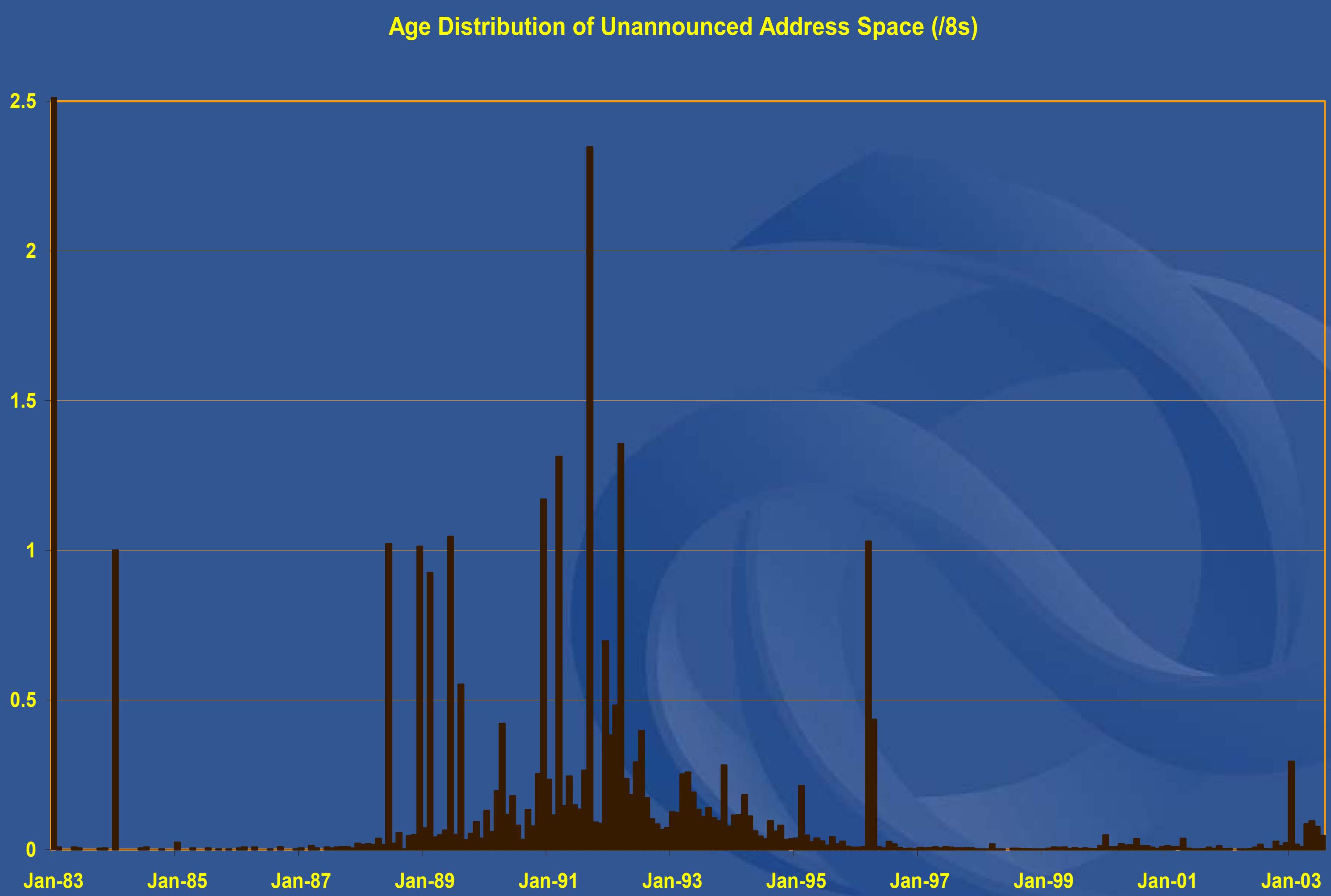
Holding Pools

- 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

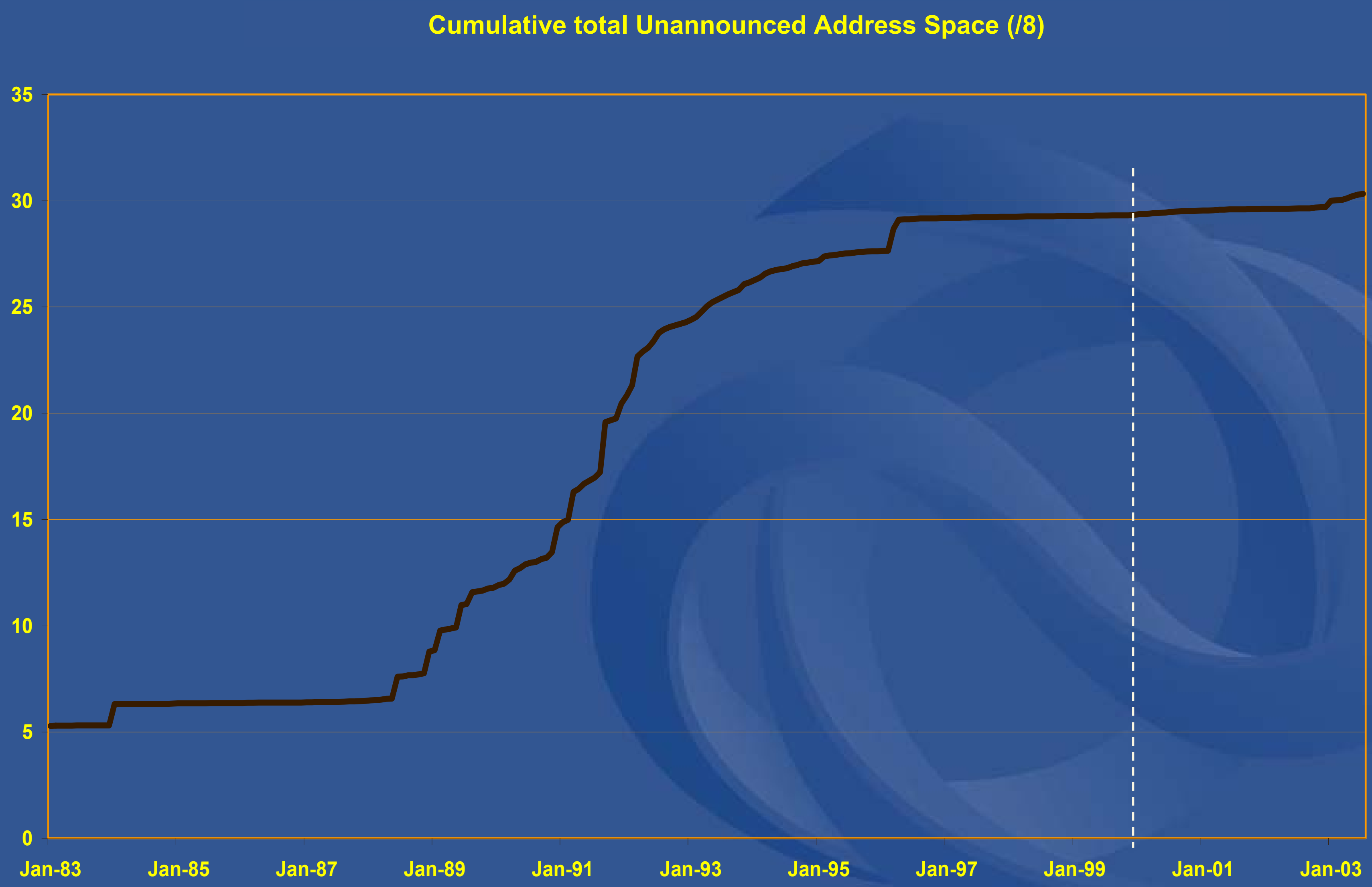
Total Allocations - Current



Unannounced pool - History



Unannounced pool - History



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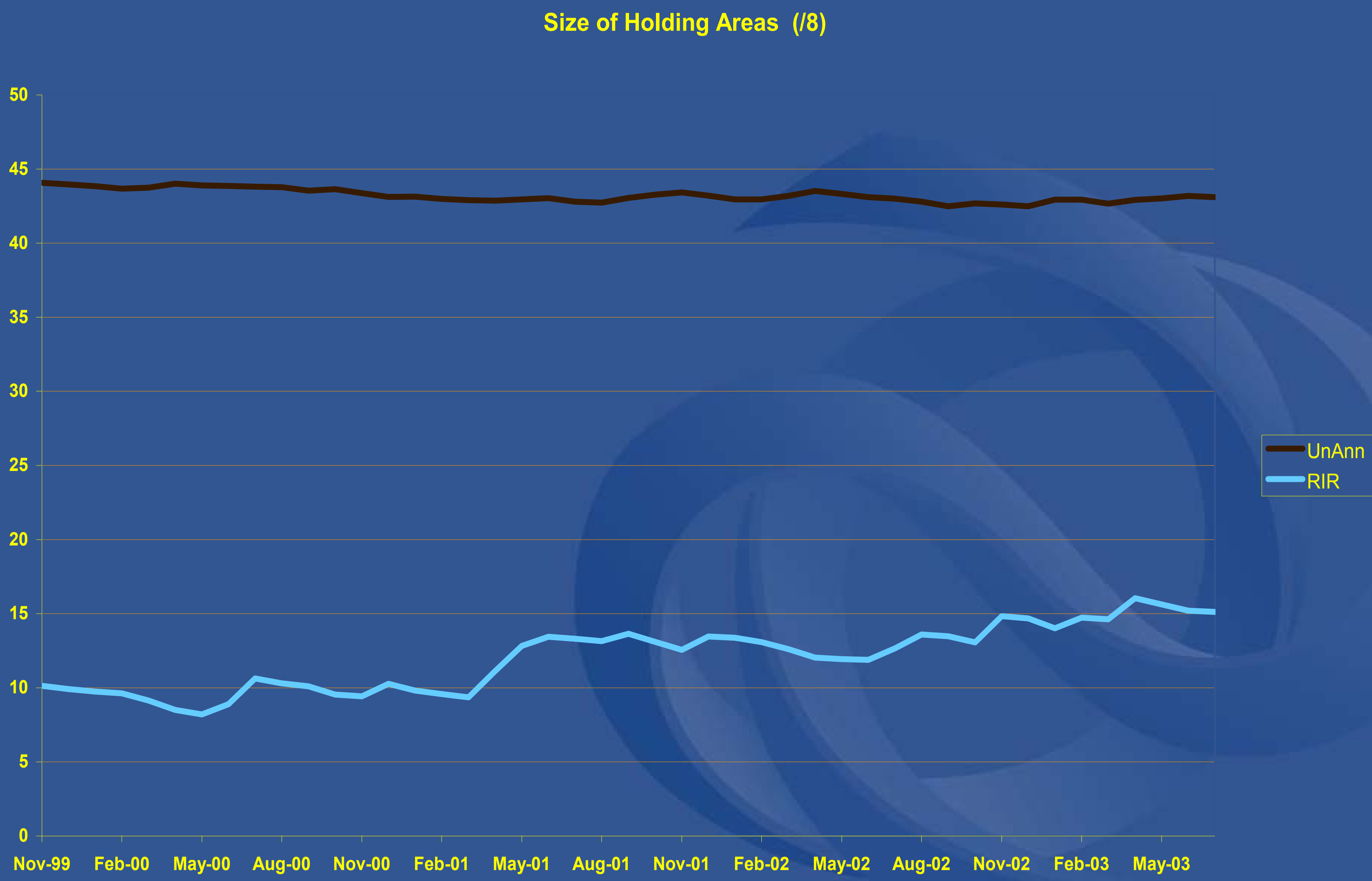
Holding Pools: RIR & Unannounced



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

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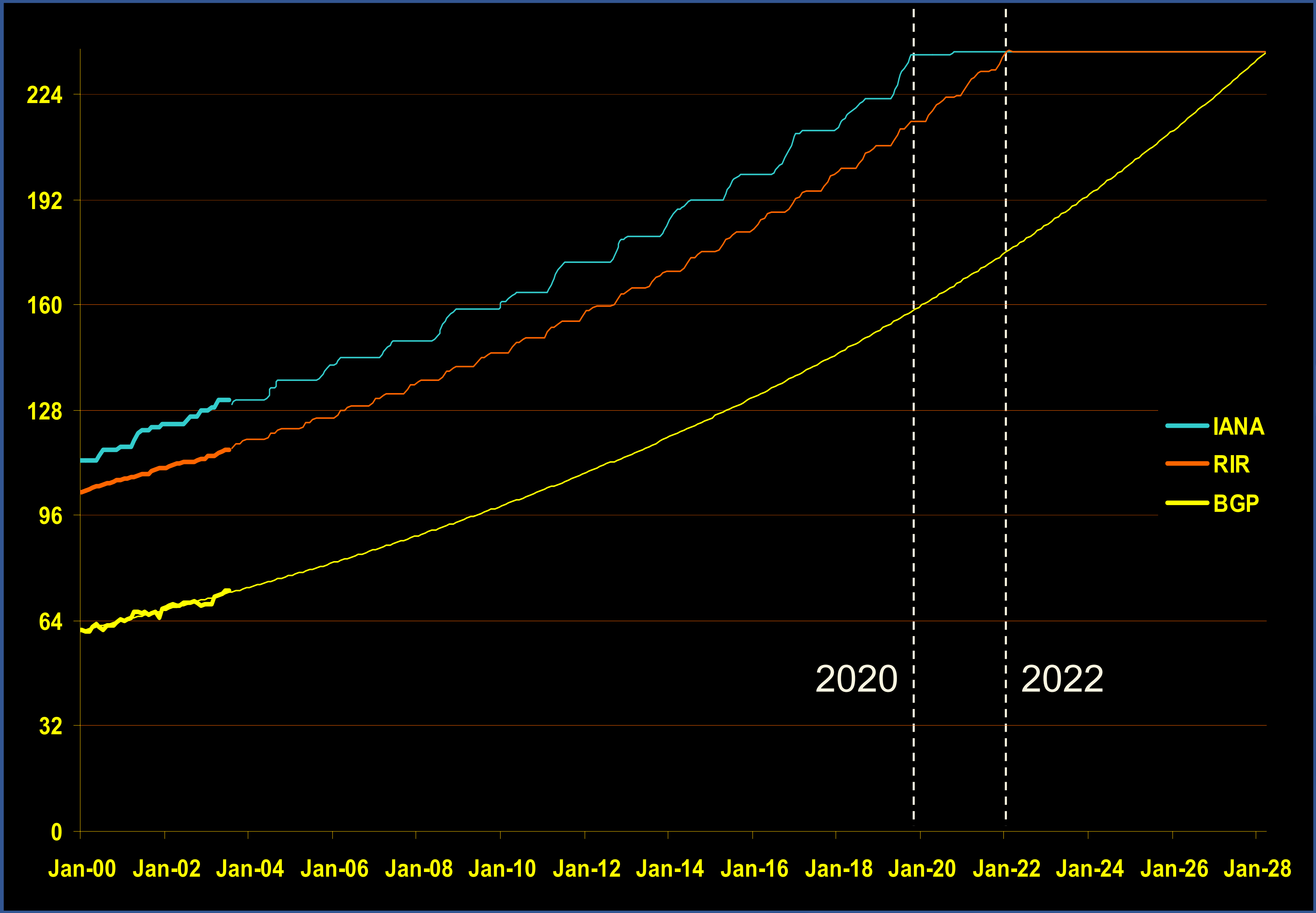
Modeling the Process

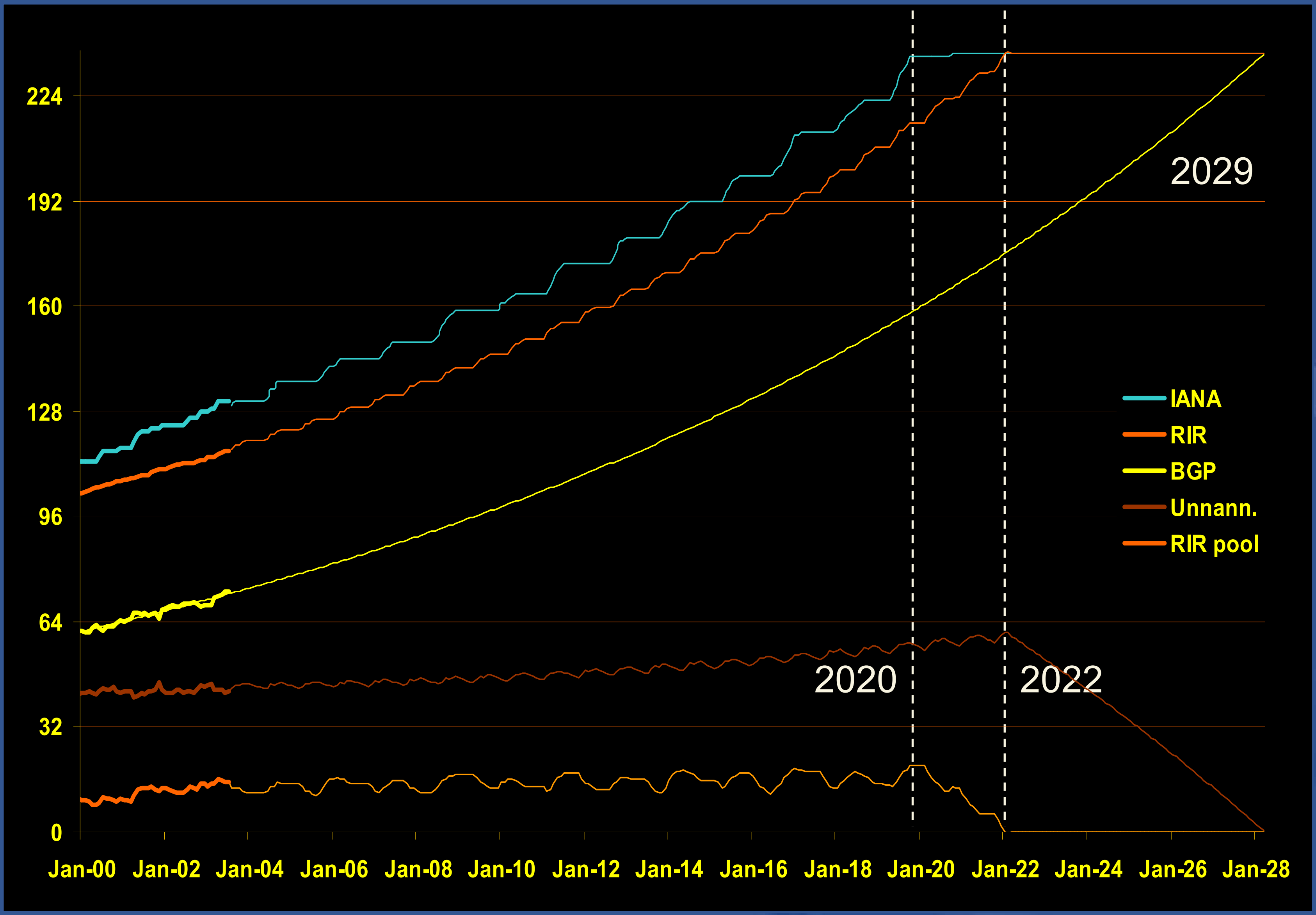
Modeling the Process

- 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

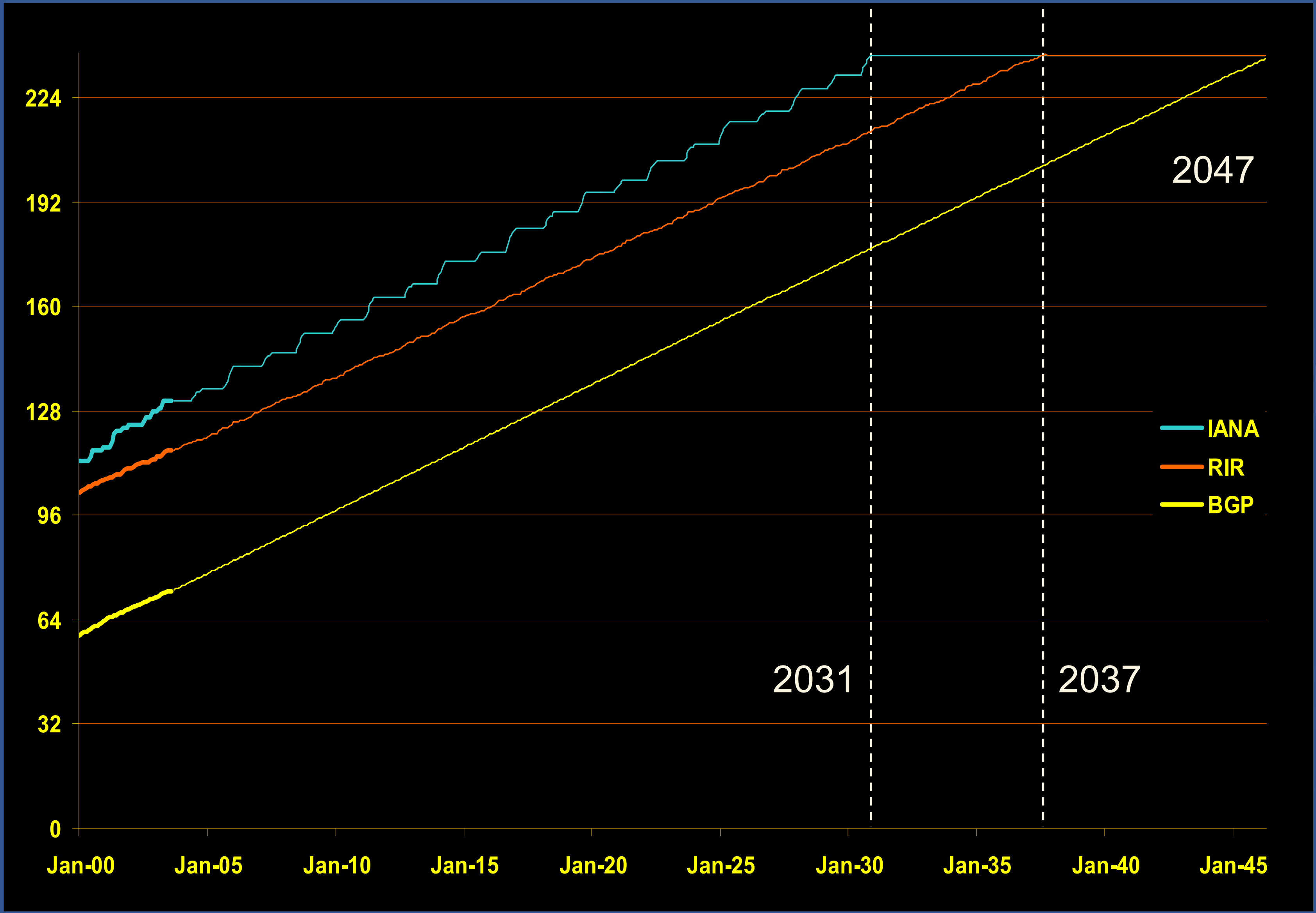
Process model - exponential



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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