Product information begins on page 2.

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Ascend

White Paper

Building Tomorrow's Internet Backbone

Table of Contents

1. Introduction

As the Internet continues to evolve into a mission critical business tool, the demands on the equipment used to build the Internet evolve as well. This document describes the challenges that the Internet is facing, and the required capabilities for network equipment. It also describes how the IP Navigator and the GRF IP switch from Ascend Communications, Inc. help meet the Internet's challenges.

An Internet History Lesson

The Internet evolved from the Arpanet–an experimental network intended to be strong enough to survive a nuclear attack. The robustness of TCP/IP and associated routing protocols led to network growth that far surpassed what the early developers envisioned. Figure 1 depicts this growth. (Time is shown on the X-axis and Internet market size is shown by the width of the bar.) Three distinct periods of Internet evolution each created additional requirements for the network infrastructure.

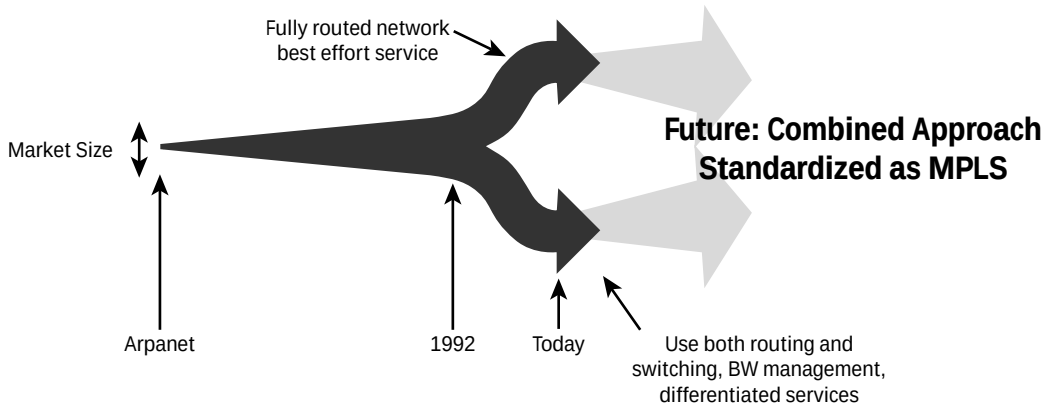

Figure 1 – Internet growth

The first period lasted from the inception of the Internet until about 1992 and used only routers. While these early routers were slow, they were sufficient to satisfy a backbone network initially built with only 56 Kbps lines. The sole important requirement was for robust routing protocols. As the Internet continued to grow, the 56 Kbps lines were upgraded to T1s (1.544 Mbps), then to many T1s, and finally to a DS3 backbone. By then, the existing routers were overwhelmed with the Internet's traffic demands.

Responding to the Traffic Growth

Starting in 1992, several Internet Service Providers (ISPs) discovered they could build higher performance networks by constructing their routed network on top of a switched Frame Relay network. They also discovered that this switched network gave them three significant advantages over a purely routed network. First, the switched network gave the service provider the important capability to perform bandwidth management – the ability of switches to determine if bandwidth along a path is fully consumed and then to find other, less busy paths. Second, it let the service providers offer multiple services (both Frame Relay and IP on a single network), expanding their revenue opportunities. Finally, the switched network offered Quality of Service (QoS), allowing time sensitive traffic, such as Web traffic, to receive higher throughput and lower delay than less time-sensitive traffic, such as e-mail. Ascend saw the need for a single network that combined the intelligence of routing with the advantages of switching. Ascend began development of IP Navigator to fill this need.

While switching solved the problem at the network's core, the number of ISPs connecting at the Internet's cross-roads – the NAPs – grew tremendously. Therefore, new routers with high packet forwarding rates and robust BGP implementations were required for these applications. Ascend also created the GRF high-performance router family which contains dedicated route processors, distributed line card forwarding, and a high speed crossbar switch rather than the traditional bus architecture of older routers. This new architecture allowed the GRF to far surpass the performance of routers based upon older architectures.

The Future: Combining Routing and Switching

The future of the Internet will use an infrastructure that combines the strengths of both high-performance routing and switching on a single network. Ascend is actively involved in the standards effort (via the Multi Protocol Label Switching [MPLS] working group within the IETF) to bring these two domains together and will fully support the standard on all of its IP products.

2. Ascend's Products

While MPLS is the end goal, it will be some time before it is standardized. Today, Ascend already has the two best-of-breed products in both routing (the GRF™ family) and switching (the CBX 500 and B-STDX families with IP Navigator). Today, each of these product families have their own unique strengths.

GRF Family of IP Switches

The GRF family of high-performance IP switches lets carriers and ISPs cost-effectively provide network access and backbone services. The GRF's unique architecture combines its Layer-3 switch with intelligent IP Forwarding Media Cards to deliver scalable performance.

The GRF products include the GRF 400 and GRF 1600. The GRF 400 supports up to four media cards for up to 4 Gb/s of bandwidth and the GRF 1600 supports up to 16 media cards for up to 16 Gb/s of bandwidth.

The GRF easily integrates into existing networks using industry-standard media types, such as HSSI, FDDI, 10/100Base-T, ATM OC-3/STM-1, ATM OC-12/STM-4 and SONET/SDH OC-3/STM-1. Support for a robust suite of routing protocols provides the flexibility and interoperability required for complex network topologies.

IP Navigator

IP Navigator is a software upgrade for the B-STDX and CBX 500 switches. IP Navigator adds IP routing capabilities, while fully maintaining the Frame Relay and ATM services that made these products market leaders. IP Navigator takes advantage of the underlying switching capabilities to provide – for the first time – guaranteed bandwidth, predictable service and end-to-end QoS for IP traffic.

IP Navigator consists of two components that can be used together or separately: edge routing and core label switching. Used alone, IP Navigator's edge routing capability allows the B-STDX and CBX 500 switches to be used as high-density access concentration routers for speeds ranging from 64 Kbps through DS3. When edge routing and core label switching are used together, the B-STDX and CBX 500 switches allow carriers to build a multiservice solution that combines three services on one network: IP, Frame Relay, and ATM.

3. Backbone Requirements

ISP Backbone Landscape

There are multiple methods for designing Internet backbones, each with different requirements. The GRF and IP Navigator provide solutions for each of these methods and requirements. The GRF delivers routed backbone capacity, while IP Navigator provides a switched backbone solution.

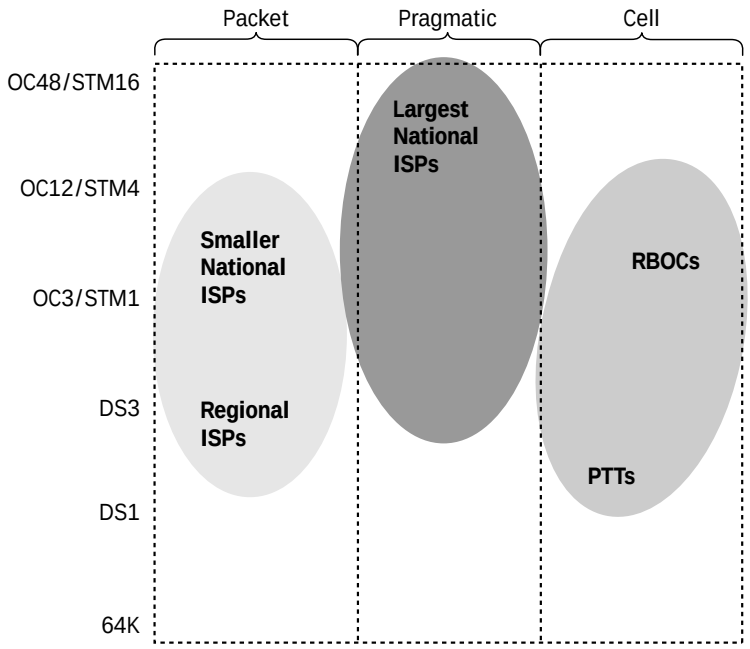

Figure 2 – Internet Provider Backbone architectures

The X-axis in Figure 2 represents the type of backbone that particular service providers prefer (ranging from purely packet routed to ATM cell-switched). The Y-axis represents the backbone speeds that providers desire about a year from now. This graph reveals three concentrated groups:

- The group at the left represents router-based networks backbones DS3 moving towards OC3/OC12 tomorrow. These network requirements are filled by the GRF.
- The group at the right represents backbones built using ATM to deliver IP with QoS. Ascend switches the IP Navigator are ideal for those needs.
- The center group represents mixed or hybrid backbones. These backbones use whatever gives them the highest throughput, whether it is routed or switched. A combination of both products will fill these needs.

Product Landscape

Figure 3 contains the information shown in Figure 2, overlaid with IP solutions from Ascend. The GRF and the B-STDS, CBX and GX productions with IP Navigator provide solutions across the entire bandwidth requirements for all sizes of Internet back bone networks.

The market leading B-STDX platform is ideal for delivering leased line services from DS0 to T1/E1, with high speed trunking at T3/E3 and OC-3/STM-1. The CBX 500 with IP Navigator provides high density concentration for T1/E1 and T3/E3 connections with trunking at OC-3/STM-1 and OC-12/STM-4. The GX 550 provides high capacity transport for IP at speeds up to OC-48/STM-16. The GRF high performance switch/router delivers high capacity IP forwarding ranging from T1/E1 to OC-12/STM-1.

The Ascend family of IP products provides multiservice solutions for the full range of IPS network architectures, delivering low speed access to high capacity backbone transport for all Internet applications. These products not only support today's best effort Internet services, but also deliver enhanced service capabilities such as Virtual Private Networks, Multicast and full QoS.

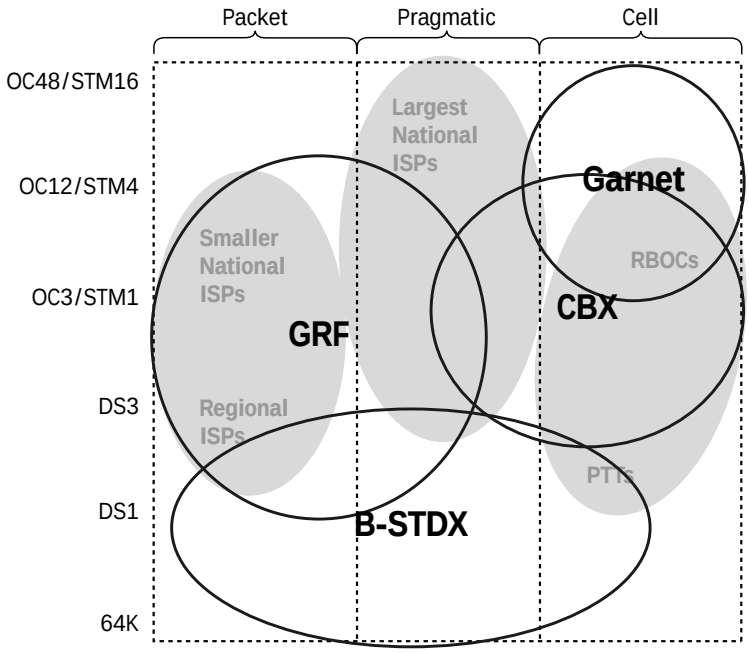

Figure 3 – Ascend's IP solutions

Combining Products to Deliver Enhanced Network Services

The GRF supports multiple high-speed media such as OC-12, delivers scalable performance, and includes a robust suite of routing protocols. IP Navigator offers guaranteed bandwidth, predictable service, and end-to-end QoS. Table 1 shows the relative strengths of each product.

Table 1 – Relative Strengths of GRF and IP Navigator.

GRF	IP Navigator
Routed Backbone	Multiservice, switched backbone
NAPs	Leased line aggregation density (64 Kbps-T1/E1)
Peering	Bandwidth management, QoS
Ethernet, FDDI, and HIPPI LANs aggregation	Carrier class networks

Combining these products in one network creates a scalable network infrastructure capable of delivering the performance and services that are required for next-generation Internet networks.

ISP POP Expansion

Ascend offers three best-of-breed solutions for the ISP POP — the MAX TNT™, the GRF, and IP Navigator-enabled switches. Each is strong enough to be sold separately into a network. Together, they form a potent combination for demanding ISPs as shown in Figure 4.

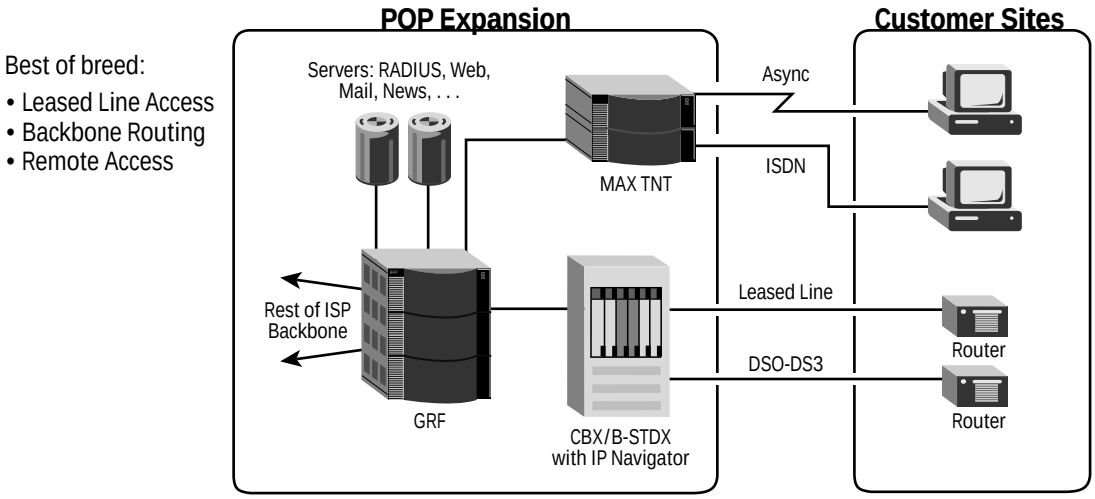

Figure 4 – Ascend's MAX TNT, CBX/B-STDX combined with IP navigator and GRF – unprecedented port density and high-speed WAN access.

Leased Line Access with IP Navigator

IP Navigator turns the B-STDX and CBX platforms into fully functional, standalone routers. It allows the B-STDX and CBX 500 platforms to route IP packets for leased line connections in the same way that the MAX TNT routes IP packets for remote access connections.

This routing capability allows ISPs to take advantage of the platforms' industry-leading port densities, detailed in Table 2. (Note that full performance is maintained at these port densities, unlike competing products.) The connection between the B-STDX and GRF can be HSSI or ATM OC-3. Additionally, in Q1 1998 both the B-STDX and CBX 500 platforms will be able to connect to the GRF using 10/100Base-T.

Table 2 – Port Densities Achievable with Platform and IP Navigator.

Access Speeds	B-STDX 9000	CBX 500
56/64 Kbps (North America & Japan)	1,344	N/A
64 Kbps (Rest of World)	1,680	N/A
T1 PPP/Frame	392	Future
E1 PPP/Frame	168	Future
DS3 PPP/Frame	28	84[1]

[1] *Requires frame cards scheduled for Q1 1998.*

POP Concentration

The GRF 400 and GRF 1600 are high-performance IP switches well suited for an ISP POP. The GRF combines excellent price and performance and price per port with a robust BGP implementation, high-density, high-speed media cards, and ultra-fast IP packet forwarding to make it ideal router for POP concentration. Unlike competing products, the GRF achieves scalable performance and can achieve the port densities outlined in Table 3.

Table 3 – Port Densities of GRF IP Switches.

Port Speeds	GRF 400	GRF 1600
DS3 or HSSI	8	32
10/100 Ethernet	32	128
FDDI	16	64
OC3 POS	4	16
OC3 ATM	8	16
OC12 ATM	4	16
OC12 POS	4[1]	16[1]

[1] *Requires frame cards scheduled for Q1 1998.*

Carrier-Class Hybrid Backbone

The combination of the IP Navigator and the GRF in the core creates a carrier-class hybrid backbone that enables network service providers to deliver enhanced network services. In Figure 5, the GRF performs POP concentration and NAP connectivity, while the switches running IP Navigator provide high density access, and switch the packets over either a Frame Relay or ATM core. This combined backbone approach has numerous advantages.

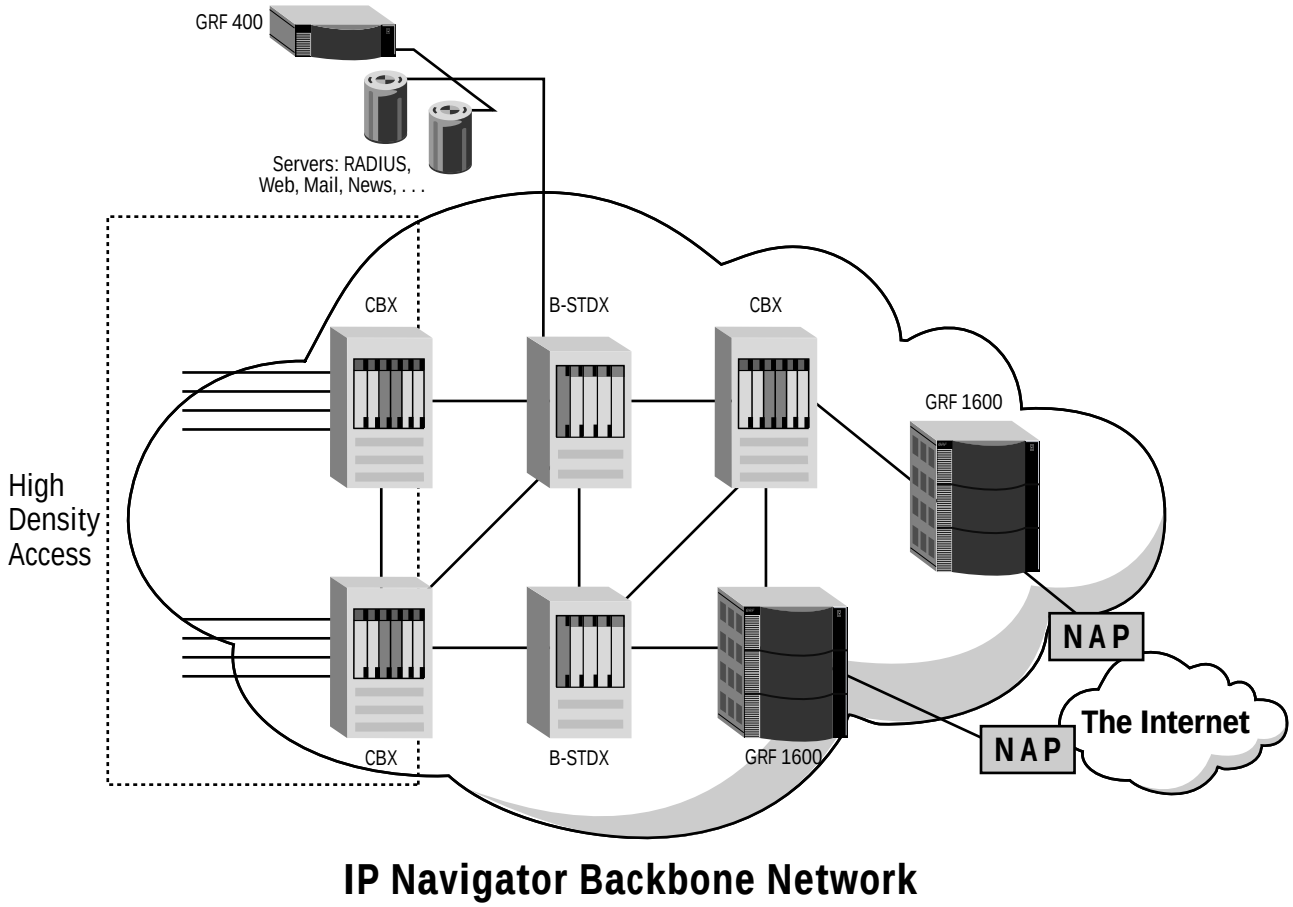

Figure 5 – Hybrid backbone combining IP Navigator and GRF

Scalability/Performance

The extensive scalability of this combined solution includes the following:

- Ability of both the GRF and IP Navigator to handle 250 routes
- High-density leased line access with the B-STDX and CBX 500 switches
- High-density Ethernet ports with the GRF for server farm applications and LAN access
- Dedicated frame/cell processors for each line card for the GRF, B-STDX and CBX 500 platforms, enabling linear performance scaling of packet/cell processing capability as cards are added

Multiple Services

The B-STDX and CBX 500 retain all of their Frame Relay and ATM functionality after IP Navigator is enabled. This allows a carrier to offer multiple services from one network, allowing cost reductions via one set of equipment and long distance lines.

IP Navigator allows multiple services (IP and Frame Relay or IP and ATM) to be offered on a single connection to a customer via separate Virtual Circuits (VCs). Each VC can be specified as either routed or switched. All packets that the customer wants routed (that is, to reach the Internet) can be sent over a specified VC that routes packets, while packets to be switched (that is, to go from a headquarters to a branch office), can be sent over VCs that perform point-to-point switching. This feature is unmatched in the industry.

QoS

IP Navigator allows carriers to provide differentiated services to selected customers using IP Navigator's QoS features. The first release of IP Navigator provides a capability known as Provisioned QoS, allowing high priority traffic (as defined by the carrier) to traverse provisioned VCs, which can have a combination of guaranteed bandwidth and lower latency. A later release of IP Navigator will allow these virtual circuits to be established dynamically when a certain type of traffic flow is observed.

Routing Protocols

Ascend's carrier-class hybrid backbone features a robust suite of routing protocols support for intra- and inter-AS routing. Both the GRF and IP Navigator separate route processing from IP packet forwarding, allowing demanding routing protocols to run without affecting the packet forward rates.

IP Navigator supports a robust implementation of OSPF, along with RIP 2, and BGP4. Together, these protocols provide intra-AS routing, BGP peering at private exchange points, and BGP connectivity to customers.

The GRF supports BGP4 and all of its extensions as well as IS-IS to function as an Inter-AS router. The GRF features a robust BGP implementation that supports more than 64 peering sessions within a single system. Even with high-speed OC-3 and OC-12 media, the GRF supports linear media and operating as an Inter-AS Peering Router.

Product Application Matrix

Table 4 shows the suitability of the GRF and IP Navigator for various applications.

Table 4 – GRF and IP Navigator–Suitability for Various Applications.

Application	GRF 400/1600	B-STDX with IP Navigator	CBX 500 with IP Navigator
Internet Routing			
Applications requiring FDDI (corporate, NAP connections)	✓		
BGP peering @ private exchange	✓	✓	✓[1]
Customer BGP peering	✓	✓	✓[1]
Customers running IS-IS protocol	✓		
Quality of Service		✓	✓
Access Aggregation			
DS0, DS1 PPP or Frame Relay switching and/or routing		✓	
DS3 PPP or Frame Relay switching and/or routing	✓	✓	✓[1]
DS1 ATM, DS3 ATM, OC3 ATM switching			✓
Backbone Switching			
Frame Relay backbone (DS3)		✓	✓[1]
ATM backbone (DS3-OC3)		✓	✓
ATM backbone OC12			✓
OC3 - OC12 Frame over SONET	✓[1]		
Multiservice: Frame Relay switching, ATM switching		✓	✓[1]
Backbone Routing			
DS3 packet – OC3 POS	✓		
OC3 – OC12 ATM	✓		
OC12 POS	✓[1]		
Other Applications			
POP concentrator	✓		
Applications requiring Ethernet (server farm)	✓	✓[1]	✓[1]
Large corporate networks	✓		

[1]*Will be appropriate for this application when frame cards are released in Q1 1998.*

The GX-550 is targeted for international availability by Q2 1998.

Worldwide and North American Headquarters
One Ascend Plaza
1701 Harbor Bay Parkway
Alameda, CA 94502, United States
Tel: 510.769.6001
Fax: 510.747.2300
E-mail: info@ascend.com
Toll Free: 800.621.9578
Fax Server: 415.688.4343
Web Site: http://www.ascend.com

European Headquarters
Rosemount House
Rosemount Avenue
West Byfleet
Surrey KT14 6NP, United Kingdom
Tel: +44 (0) 1932.350.115
Fax: +44 (0) 1932.350.199

Japan Headquarters
Level 19 Shinjuku Daiichi-Seimei Bldg.
2-7-1 Nishi-Shinjuku
Shinjuku-ku, Tokyo 163-07, Japan
Tel: +81.3.5325.7397
Fax: +81.3.5325.7399
Web Site: http://www.ascend.co.jp

Asia-Pacific Headquarters
Suite 1908, Bank of America Tower
12 Harcourt Road
Hong Kong
Tel: +852.2844.7600
Fax: +852.2810.0298

Latin, South America and the Caribbean Headquarters
One Ascend Plaza
1701 Harbor Bay Parkway
Alameda, CA 94502, United States
Tel: 510.769.6001
Fax: 510.747.2669

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