



Composite markets materials and processes: Where we are, where we are headed

2021 IACMI Winter Meeting

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The year that was

- Aerospace
- Automotive
- Wind energy
- Marine/RVs/sports
- Pressure vessels
- Urban air mobility

Back to the future

- Drivers
- Challenges
- End markets to watch
- Materials to watch
- Processes/technologies to watch
- Composites 5.0



CompositesWorld

- Technical trade publication serving the global composites manufacturing industry
- Emphasis on coverage of software, materials, equipment and processes used to design, fabricate and finish composite parts and structures
- Ryan Delahanty (publisher), Jeff Sloan (editor), Ginger Gardiner (senior editor), Hannah Mason (associate editor), Grace Nehls (assistant editor), Scott Stephenson (conferences, strategy) Peggy Malnati (contributor)
- [CW printed monthly magazine](#)
- [CW Today newsletter](#) (three days per week)
- CW *EXTRA* technology newsletter (twice per month)
- [CompositesWorld.com](#)
- [CW Talks: The Composites Podcast](#)



Aerospace: Pre-COVID-19

- Highest value end market for composites
- Airbus A350 10 shipsets/month
- Boeing 787 14 shipsets/month
- Boeing 777X close to first flight
- Boeing 737 MAX grounded
- Record passenger air travel 2019
- Boeing NMA?
- Boeing/Airbus new single-aisles 2023-2025
- Composites supply chain gearing up
 - Spirit AeroSystems ASTRA panel
 - Clean Sky 2
 - Carbon fiber capacity
 - Thermoplastics
 - Liquid resin infusion

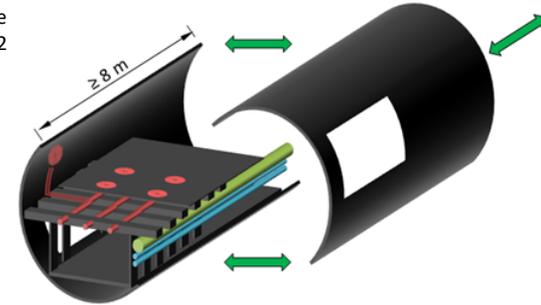


Boeing 737s, not flying.
Source: WSJ

Clean Sky 2 Multifunctional Fuselage Demonstrator. Source: Cleans Sky 2



Thermoplastic fuselage clip for Airbus A350. Source: CW



Airbus A350 assembly. Source: Airbus



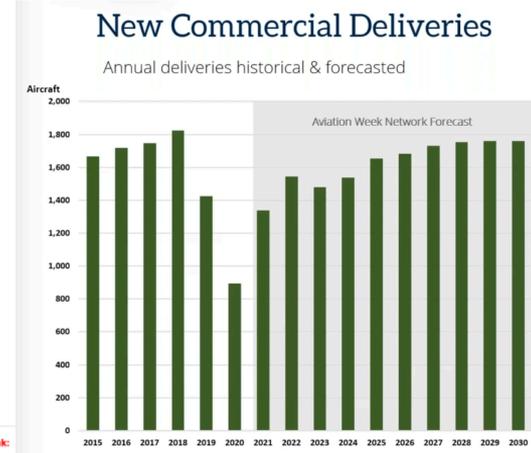
Spirit AeroSystems' ASTRA fuselage demonstrator, Paris Air Show 2019.
Source: CW

Aerospace: Post-COVID-19

- Passenger air travel down 60-70% through mid 2021
- No NMA from Boeing
- Domestic routes will recover before international
 - 787, A350 reduced to 4-5 shipsets/month
- New single-aisles pushed out to 2025-2027
- 400 737 MAX aircraft built, in storage
- Boeing and Airbus to produce 1350 aircraft in 2021
 - Market demand less than that
 - Maintaining supply chain functionality
 - AW 2030 forecast: 1,750 aircraft; <2017 total
- Airbus strength vs. Boeing
 - Airbus aircraft better aligned to market needs
 - Boeing lacks competitor to A321XLR
 - Early February 2021, AW reports Boeing working on twin-aisle competitor to A321XLR
 - 737 MAX still strong cash-producer
- Airbus ZEROe project
- Hydrogen-powered propulsion by 2035

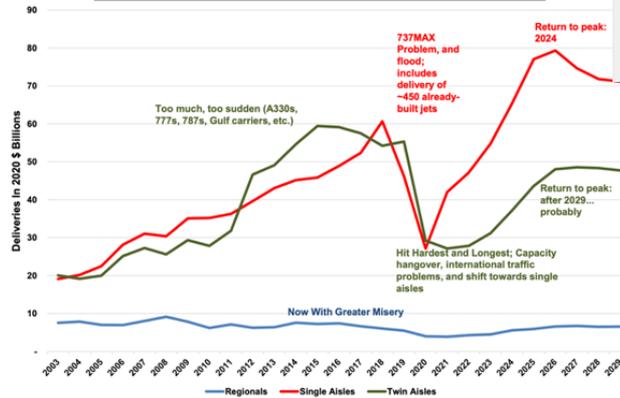


787-3? Source: Boeing



Source: 2021 Commercial Aviation Fleet & MRO Forecast, Aviation Week Network, Copyright 2020.

The Air Transport Market By Segment



© 2020 Teal Group Corporation

Aircraft production recovery, by type. Source: Teal Group



Renderings of the Airbus ZEROe aircraft. Liquefied hydrogen would be stored in possibly composite PVs located in the aft fuselage. Source: Airbus

Aerospace: What does it mean?

- Timelines have changed, *trends* have not
- High-rate, high-volume composites fabrication still a must for next-gen aircraft:
 - 60-100 single-aisles per month
 - Out-of-autoclave M&P
 - Thermoplastics
 - Infusion
 - Resin transfer molding
 - Automation
 - In-situ inspection
 - Qualification/certification of new M&P



Airbus A220 wing, infused in Belfast, Northern Ireland by Spirit AeroSystems.

Source: Spirit AeroSystems

Airbus A320 spoiler, made via RTM. Source: CW



Irkut MC-21 infused wing skin.

Source: Aerocompositi



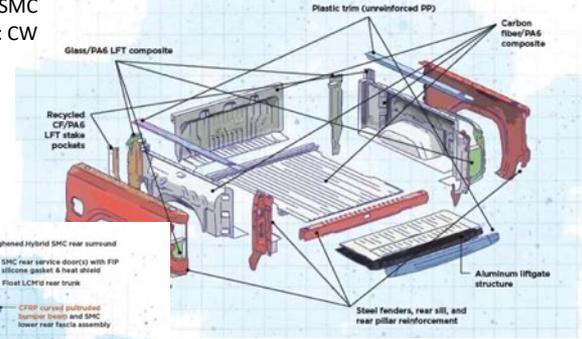
Fives Viper AFP with in-process inspection.

Source: Fives

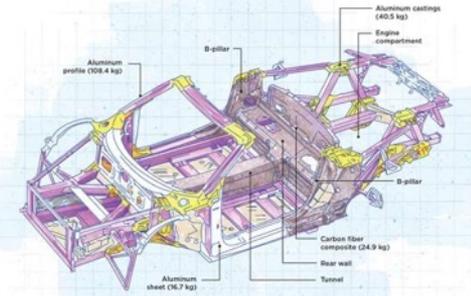
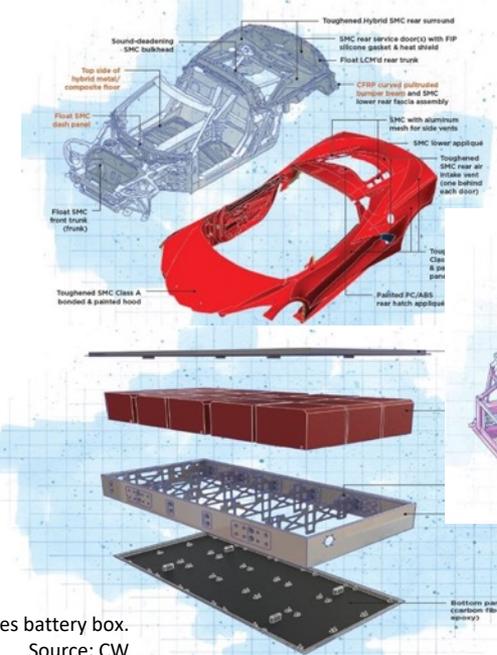
Automotive: Pre-/Post-COVID-19

- Incremental composites penetration
- BMW i3, 7-Series
- Audi A8, R8
- Corvette
- GMC Sierra Denali
- Honda Ridgeline
- Electric vehicles (battery enclosures)
- EVs sales less harmed by pandemic than ICE vehicles
- Hurdles/barriers
 - Cost
 - Cycle time
 - “Weird” supply chain
 - Customer disconnect — vehicle weight

GMC Sierra Denali CarbonPro SMC pickup box. Source: CW



2020 Corvette Stingray. Source: CW



Audi R8 MSS CFRP rear wall and tunnel. Source: CW

TRB Lightweight Structures battery box. Source: CW

Wind: Pre-/Post-COVID-19

- Largest composites market by volume
- Pultruded carbon fiber spar caps
- Glass fiber shells, shear webs
- Global wind installations
 - 71.3 GW 2020 (739 GW total)
 - 78.0 GW 2021 (817 GW total)
 - 2050 global total: 6,044 GW
- Average blade length increasing:
 - 2018 onshore rotor diameter: 110m
 - 2020 onshore rotor diameter: 158m
 - 2025 onshore rotor diameter: 170m
- Strong growth in offshore wind installs globally
 - 6.1 GW 2019
 - 21.5 GW 2025
 - 31.9 GW 2030
- Softening in 2021: Hexcel, Vestas closings (Colorado)
- Oil and gas
 - Baker Hughes Onshore Composite Flexible Pipe



GE Haliade X wind turbine. 220m diameter rotor, 12-MW capacity. Source: GE



Wind blade layup with balsa core and glass fiber. Source: Aeris Wind Energy



Wind blade mold closing. Source: Aeris Wind Energy



Pultruded carbon fiber spar cap for wind blades. Source: CW

Marine/RVs/sporting goods

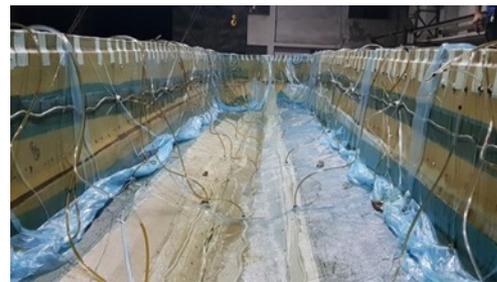
- COVID winners
- U.S. recreational marine sales:
 - 2020 YTD +9% over 2019
 - Sept. 2020 second-highest single-month total of new powerboats sold in more than a decade
 - 2020 outboard motor boat sales up 18%
 - Increased use of foiling technology increases composites use
- U.S. RV sales:
 - 2020 YTD +4.5% over 2019
 - 500,000+ units to be sold in 2021
- Global bicycle sales
 - CAGR 7.8%, 2019-2024



Candela Boats *Seven* speedboat, with electric motor and range of 50 nautical miles. Source: Candela Boats



Arevo additively manufactured, all carbon fiber, made-to-order *Superstrata* bicycle. Source: Arevo

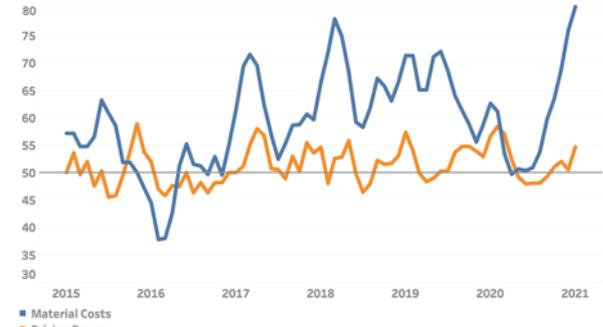


60-foot vacuum-infused boat hull. Source: Poly Glass (India)

Glass fiber gun roving shortage

- *Strong marine, RV, hot tub sales* in U.S. have increased demand for glass fiber gun roving
- Pandemic and changing supply dynamics creating shortage
- *Most gun roving supplied by Jushi*, Chongqing Polycomp International, Congqing Sanlei Glass Fiber, Jiangsu Changhai Composite Materials
- Pre- and early-pandemic, *Chinese gun roving exporters paid U.S. tariff (25%)* to maintain market share
- As China recovered, *domestic gun roving demand increased*; simultaneously, U.S. demand increased
- *Chinese exporters no longer motivated to pay tariff*; early January, 20% price increase for Chinese gun roving in U.S.; supply and pricing pressure on U.S. fabricators
- [Global shipping container imbalance](#); ports slow to unload; not enough empty containers returning to China

Glass Fiber Material Costs & Pricing Power (3MMA)



Source: CW

World Container Index - Assessed by Drewry \$ per 40 ft container

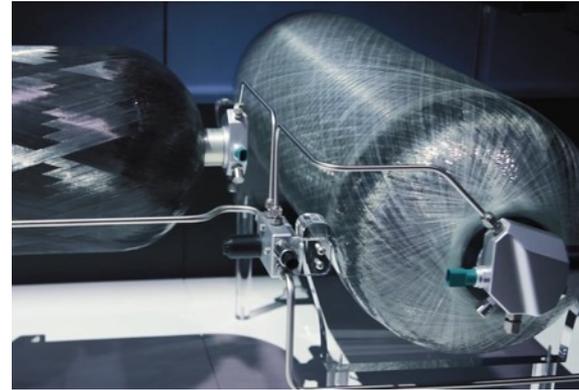


Eastbound container freight rates have more than doubled, eclipsing all historical highs. SE Asia to US rates have risen from from \$2,000 to \$4,500 per 40-ft container.

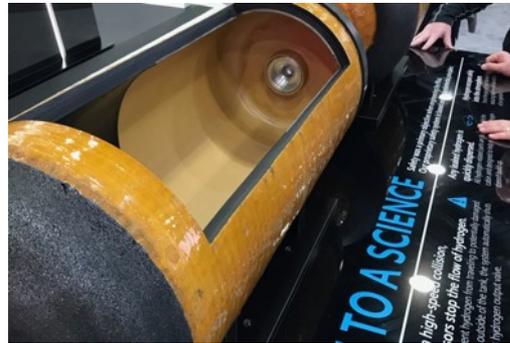
Source: [Hillebrand](#)

Pressure vessels

- Compressed natural gas (CNG), liquified natural gas (LNG), hydrogen (H₂, gas and liquid)
- Type IV tanks: Polymer liner, CF overwrap
- Buses, trucks, cars, aircraft
- Global natural gas vehicle (NGV) sales:
 - 24.4 million units 2020
 - 37.4 million units 2027
- Carbon fiber demand ([Pichler/Roberts](#)):
 - 13,100 MT 2021
 - 20,230 MT 2026
- Fuel cell electric vehicles (FCEV)
 - Hydrogen-powered
 - Toyota, Hyundai, Honda
 - Lack of refueling infrastructure
- Hydrogen combustion for aircraft
 - EU stipulation for COVID relief
 - Airbus demonstrate flight by 2035 (ZEROe)
 - Liquid hydrogen (cryo temp storage)



Carbon fiber hydrogen pressure vessel made by Faurecia for Hyundai truck. Source: Faurecia



Cutaway of carbon fiber hydrogen pressure vessel for Toyota Mirai fuel cell vehicle. Source: CW



Universal Hydrogen pressure vessel module for aircraft hydrogen storage. Source: Universal Hydrogen

Urban air mobility (UAM)

- Air taxi service or cargo transport (Uber Elevate)
- Intracity, intercity, regional (point-to-point)
- Piloted and autonomous
- 2-6 passengers
- 25-400 km
- Electric VTOL
- Hundreds of developers, few serious (i.e., have money):
 - Beta Technologies
 - EHang
 - Joby Aviation
 - Lilium
 - Pipistrel
 - Volocopter
 - Wisk
 - Vertical Aerospace



Beta Technologies' ALIA 250C is a piloted eVTOL that seats up to six passengers. Source: Beta Technologies



Wisk's Cora autonomous eVTOL is a two-seater with a range of 40 km. Source: Wisk



Joby Aviation's unnamed and autonomous tiltrotor eVTOL seats up to two passengers. Source: Joby Aviation

Urban air mobility (UAM), cont'd

- Current programs in prototyping and early demonstration phase
 - Service launch 2023
 - Expansion 2023-2026
 - Scale-up 2028
- 2035: 50 markets, 10,000 units/year (Uber)
- Aerospace quality at automotive quantity (somewhat)
- What the composites industry must provide:
 - 4,500 MT of CF per year
 - Automation
 - Repeatability
 - Inline inspection
 - Minimal waste
 - Sustainability



Fabrication of the Beta Technologies ALIA at Blue Force Technologies.
Source: Blue Force

Drivers

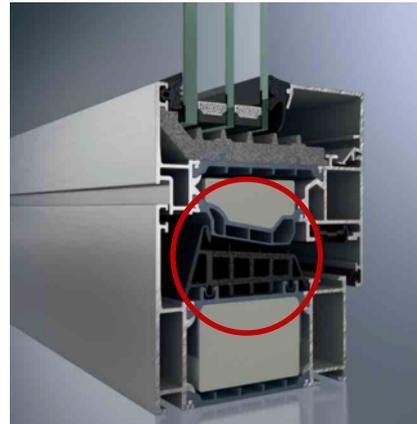
- Weight, weight, weight (did I mention weight?)
- Design flexibility
 - Fiber optimization
- Variety
 - Resins, fibers, tooling, processes
- Durability
 - Fatigue, strength, toughness
- Sustainability
 - Enabler to meet green challenges
 - Fuel efficiency
- The customer
 - Customer needs align with composites capabilities
 - Aerospace, automotive (EV, not ICE), wind

Challenges

- Cost (unit)
- Complexity (see "Variety" above)
- Cycle time (see "Variety" above)



Applied Electric Vehicles powertrain developed with Teijin. Weight reduction increases EV range. Source: Teijin



Complex pultruded composites provide high insulation properties for window systems. Source: Schüco



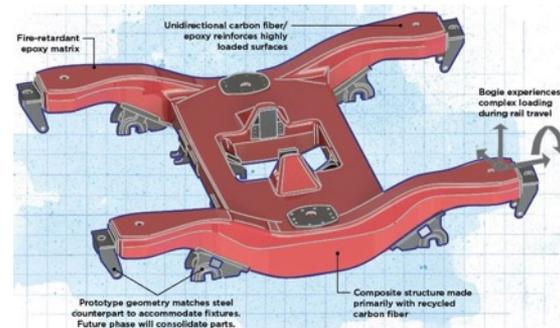
Composite Advantage's pilings offer a high strength-to-weight ratio and can reduce the number of pilings needed in a marine structure. Source: CW

End markets to watch

- Composites industry built on aerospace, automotive, wind energy, marine
- Future rests with end markets currently under-served or just beginning to understand composites' value proposition
- Cost-competitive lightweighting
 - Urban air mobility
 - Building and construction
 - Infrastructure
 - Oil and gas
 - Trucking
 - Rail



11,000 kilometers of GFRP rebar reinforce a concrete flood mitigation channel in Jizan, Saudi Arabia, and enable its 100-year service life. Source: Mateenbar



Composite rail bogie fabricated with recycled carbon fiber. Source: CW



Composite panels on the Museum of the Future in Dubai, UAE. Source: CW



Composite panels used to produce Wabash refrigerated trailers. Source: Wabash

Materials to watch

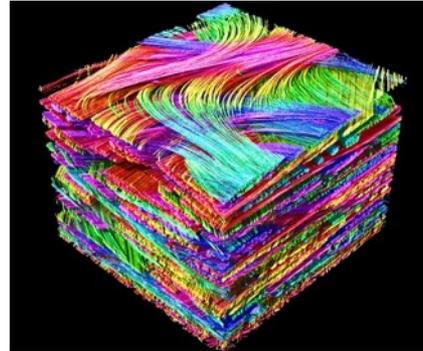
- Thermoplastics
 - PAEK, PEKK, PEEK
 - UD tapes
 - In-situ consolidation
 - Aerostructures (Clean Sky 2); fuselage, wing ribs
- Recycled carbon fiber
 - Quality standardization
 - Applications
 - Sustainability
- Reprocessable thermosets
 - Cures like thermoset, reformable beyond T_g
- Graphene
 - The next nanomaterial, or better?
- Ceramic matrix composites
 - Aeroengines hot zones
- Carbon/carbon
 - Hypersonics

Processes/technologies to watch

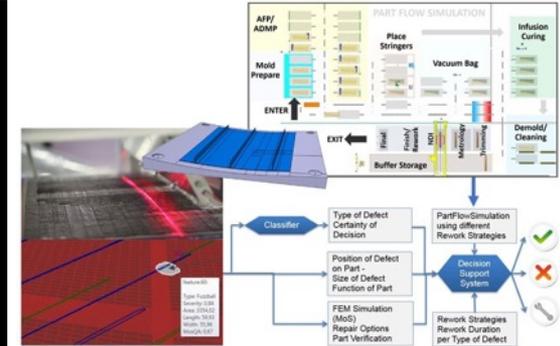
- Design and process simulation
 - Predicting material and process behavior
- Virtual testing
 - Qualification acceleration
- Industry 4.0
 - Harnessing, deploying meaningful data
 - Digital twin
- Liquid resin infusion
 - Wing skins, spars
- Resin transfer molding
 - Wing ribs, spoilers, tails, ailerons
- In-situ thermoplastics consolidation
 - Consistent temperature, pressure
- In-situ process/quality control
 - Laps, gaps, wrinkles, FOD, cuts, cure
- In-service health monitoring
 - Microcrack/damage detection; de-icing
- Injection overmolding
 - Continuous fibers meet injection molding
- Additive manufacturing
 - Polymer, metallic tooling

Composites 5.0

- Unification of composites design, process, manufacturing innovation, efficiency
- Necessary for next-generation composites fabrication, technology maturation:
 - Design and process simulation
 - Virtual testing/qualification
 - Advanced tooling materials/control
 - Process automation
 - Digital twinning
 - Advanced process control
 - In-situ quality control
 - Manufacturing data functionalization
 - In-situ health monitoring
 - Repair



Orientation analysis on a glass fiber-reinforced SMC. Source: IAM-WK/KIT



Inline defect control for CFRP-stiffened panels. Source: Profactor

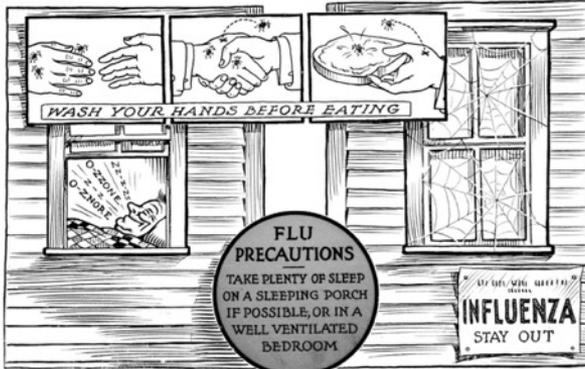


Automated cutting table line at Spirit AeroSystems (Prestwick) for A320 spoiler production. Source: CW



ZLP's autonomous work cell uses an AI-driven work cell to lay up a composite fuselage panel. Source: ZLP Augsburg, DLR

Get the Anti "Flu" Habit



How to Make Mask for Prevention of Influenza



Instructions as to the making and use of masks have been sent out by the provincial board of health. These are to be used when taking care of influenza patients, and beginning on Thursday morning on all trains and street cars in the province. Here is the method of making the mask, published in The Bulletin some days ago and here repeated by request.

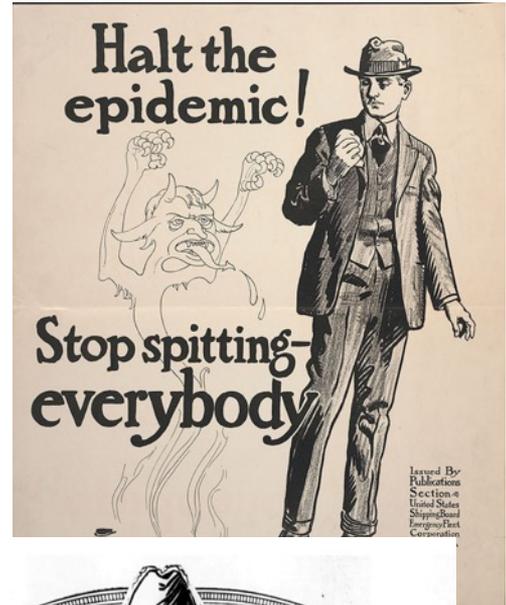
To Make a Mask—Take a piece of ordinary cheesecloth, 12 1/2 inches. Next fold this to make it 6 1/2 inches. The cord about 10 inches long at each corner. Apply over mouth and nose as shown in the picture.

To be worn in the sick room when taking care of the patient and on street cars and railway trains.

Keep the nose and mouth covered while coughing or sneezing.

A mask should not be worn more than two hours.

They Improve the Looks of Some People



Wear Your Masks
Obey the City Ordinance



Questions?

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